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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXIV.—*Further Studies of the Drainage Features of the Upper Ohio Basin;* by T. C. CHAMBERLIN and FRANK LEVERETT.*

Introduction.

IN the year 1885 the senior writer, in association with Mr. G. K. Gilbert, made a study of the drainage and drift phenomena of the upper Ohio basin. In 1886 work was resumed but was interrupted by other duties. In 1890 the junior writer, working under the direction of the senior writer, gathered data relative to the drainage history of the region while tracing the group of terminal moraines across northwestern Pennsylvania. During the present year he has undertaken a more systematic study of the subject.

We have found the work of Mr. J. F. Carll, of the Pennsylvania Geol. Survey, on the old drainage systems of the region especially valuable and admirable.† We are also indebted to the contributions of Messrs. Chance,‡ White,§ Stevenson,‖

* Presented in abstract to the Geological Society of America, Dec. 31st, 1893.

† Penn. Second Geol. Survey, Rept. III, 1880, pp. 1–10, 330–439; Rept. IIII, 1883, pp. 1–147, 169–175, 219–406.

‡ Penn. Second Geol. Survey, Rept. VV, 1880, pp. 17–20.

§ Penn. Second Geol. Survey, Rept. Q, 1878, pp. 9–17, QQ, 1879, pp. 10–20. This Journal, III, vol. xxxiv, 1887, pp. 374–381. Bull. Geol. Soc. Amer., vol. i, 1880, pp. 477–479. Also discussions of drift and drainage features incorporated in the detailed geology of the several counties covered by reports Q, QQ, QQQ, QQQQ, namely, Beaver, North Allegheny, South Butler, Lawrence, Mercer, Crawford and Erie.

‖ Penn Second Geol. Survey, Rept. K, 1876, pp. 11–19, KKK, 1878, pp. 251–263. This Journal, III, vol. xv, 1878, pp. 245–250. Proc. Amer. Phil. Soc., vol. xviii, 1880, pp. 289–316.

Lewis,* Wright,† Lesley,‡ Spencer,§ Randall,‖ Foshay,¶ and Hice.**

Probable old Drainage Basins.

We follow Carll in the general view that the present drainage system of the upper Ohio basin has been formed by the union of several pre-glacial systems that formerly flowed into what is now the Lake Erie basin. These were blocked up by the ice of the early part of the glacial period, which invaded their lower courses and forced them to flow over low divides and unite to form a common southwestward flowing system nearly parallel to the border of the ice. In this there is a strong analogy to the upper and middle Missouri system believed to have been formed out of numerous northward, northeastward and eastward flowing streams forced to unite along the edge of the ancient glacier, as determined by the studies of Todd, Salisbury and the senior writer.

If this view be correct, and a part of the purpose of this paper is to add data in support of it, each of the united sections must be considered separately in determining their pre-glacial and glacial history. Each section may indirectly help to interpret the others but it will be rather by the suggestiveness of analogy than by the direct force of specific evidence. We regard the evidence of the union of separate pre-glacial basins as clear and decisive in at least three cases, as highly probable in another, and as rather weak in another, at the present stage of investigation. These may be treated briefly in succession beginning with the uppermost.

The Upper Allegheny Basin.—Three specific lines of evidence support each other in showing that the uppermost section of the present Allegheny formerly discharged into the Lake Erie basin. (1) There is a notable constriction of the valley near Kinzua, Pennsylvania, from its usual breadth of a

* Penn. Second Geol. Survey, Rept. Z, 1884, pp. 141–202, 279.

† This Journal, July, 1883; Proc. A. A. A. S., 1883, pp. 202–207; The Glacial Boundary. Proc. Western Reserve Hist. Soc., 1884, 86 pages; Bull. U. S. Geol. Survey, No. 58, 1890, pp. 39–110; This Journal, Nov., 1892. Also discussions of the drift and drainage features of this region embraced in the "Ice Age in North America" (1889), and in abbreviated form in "Man and the Glacial Period" (1892).

‡ Penn. Second Geol. Survey, Rept. Q, 1878, pp. XXIV-XLIII; Rept. III, 1880, pp. XIII-XVII; also various footnotes in (III) and (IIII); Rept. Z, 1884, pp. V-XLIX.

§ Penn. Second Geol. Survey, Rept. QQQQ, 1881, pp. 387, 405.

‖ Penn. Second Geol. Survey, Rept. IIII, 1883, pp. 1–30, 309. We are also indebted to Mr. Randall for notes on a detailed study of the distribution of the attenuated drift in the vicinity of Warren, Pennsylvania, in which the distribution of the bowlders together with their altitude has been determined with care.

¶ This Journal, Nov. 1890. Bull. Geol. Soc. Amer., vol. ii, 1891, pp. 457–464.

** Bull. Geol. Soc. Amer., vol. ii, 1891, pp. 457–464: Science, vol. xxii. Sept. 29, 1893, p. 170. We are also indebted to Mr. Hice for favoring us with the results of careful observation on the distribution of the drift and the depth of hannels in the vicinity of Beaver, Pennsylvania.

mile or more to less than one-fourth of a mile. This constriction appears clearly to be the point at which a former col was located and across which the stream was forced when reversed. (2) From this point the buried rock floor of the valley slopes *northward* to the vicinity of Steamburg, New York, in direct opposition to the present flow of the river. (3) Here it is met by a buried rock floor sloping with the present stream, but from this point there is a broad continuous valley deeply filled with drift leading westward and northward along the line of the upper Conewango (reversed), and the lower Cattaraugus valleys to the Lake Erie basin. The evidence of this is in part shown diagrammatically in the accompanying section

1.

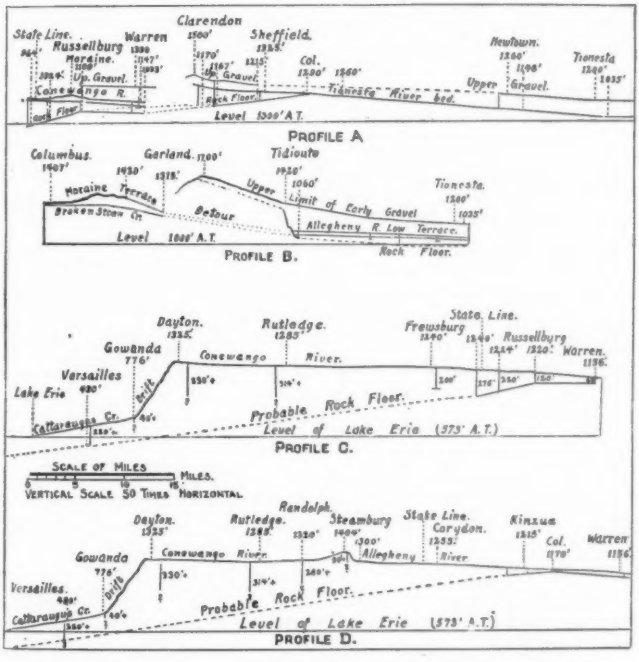


Figure 1. *Profile A* shows the erosion interval between the early glacial gravels and the late glacial or moraine-headed terrace in the Conewango valley and their altitudes compared with the head of the early glacial gravel train on the Tionesta at Clarendon. With the exception of the rock floor the fluvial planes on the Conewango and upper Tionesta belong to different drainage basins; the section is accordingly broken between Clarendon and Warren. The upper of the two broken lines connecting the rock floor at Clarendon with that near Warren was certainly reached by pre-glacial streams, and possibly the lower one. Else-

(Profile D, fig. 1). All but the last of these significant features were noted by Mr. Carll. Having no opportunity to examine the upper Conewango and Cattaraugus valleys he suggested an outlet by the way of the Cassadaga valley. In favor of the route here given we note (1) the greater width of the Conewango valley (two miles or more), (2) its more direct course to the lake basin (see accompanying map), and (3) the presence of a much deeper buried channel. Three wells along it penetrate drift to depths of 284, 314, and 330 feet respectively without reaching rock, while a fourth at Versailles, seven miles from the lake, penetrates to a point 95 feet below the lake level (aneroid) without reaching rock bottom, whereas on the Cassadaga line the rock floor opens out to the Lake Erie basin at an altitude of about 200 feet above the lake.

The general configuration of the drainage features of the region support this view of reversal as may be seen in part by consulting the accompanying map of restored drainage (map 2). The naturalness of this restored system lends support to the more positive evidence.

We note in passing that on this line as well as other pre-glacial drainage lines of this region the northward slope of the rock floor is probably somewhat accentuated by a northward differential depression. We would also note that rock excavation by an interglacial stream may have occurred along this line in the vicinity of the lake basin, it being not improbable that an interglacial stream would have had its source somewhat south of the present divide, which is a moraine of late glacial age. Both factors need to be eliminated in determining the rate of slope of the rock floor of pre-glacial times. The present rate seems too great for the nature of the valley. It may also be necessary to make allowance for excavation by ice or by subglacial water in the portion of the valley within the glacial boundary, but such excavation could not have occurred in the portion of the valley with north-sloping floor that lies outside the glacial boundary, i. e. between Kinzua and Steamburg.

where on this and the three profiles subjoined, broken lines indicate not *alternative* but *probable* positions of the fluvial planes or deposits to which they apply.

Profile B shows the erosion interval between the early glacial gravel and the moraine-headed terrace on the Allegheny near Tidioute, Pennsylvania, together with the head of the early gravel train on Tidioute creek and the later gravel on Brokenstraw creek. The Brokenstraw makes a detour to the east to join the Allegheny. The detour is indicated by dotted lines, and the section is broken at Garland where the stream turns eastward.

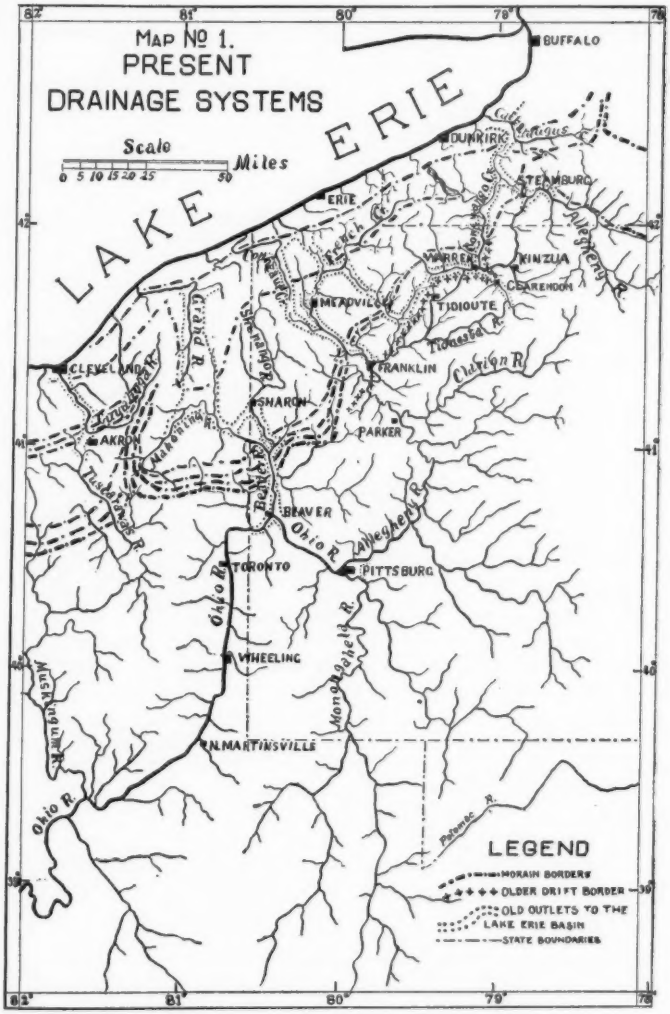
Profile C shows evidences of reversal of drainage on the Conewango valley. On this and the succeeding profile the vertical lines beneath the line of the present stream show the depth to which wells have reached. If no rock was encountered the sign (?) is introduced.

Profile D shows the evidence for reversal from the Kinzua col northward along the course of the old outlet.

The Upper Tionesta-Conewango Basin. — Mr. Carll also called attention to the evidence of reversal of drainage in the Tionesta and Conewango basins, which are connected with the present Allegheny at Warren below the old col near Kinzua. There is evidence here of the same decisive nature as that cited for the upper section of the Allegheny. The abandoned northward outlet of the upper Tionesta leading to the present Allegheny near Warren is very plainly outlined, and the numerous oil wells of the region show that the rock floor of the abandoned channel slopes northward. The old col where reversal took place is readily located near Old Sheffield (Barnsville P. O.), where the stream enters a narrow gorge scarcely one-fifth the width of the abandoned channel, the latter being 60 to 120 rods wide while the new gorge is but 10 to 15 rods.

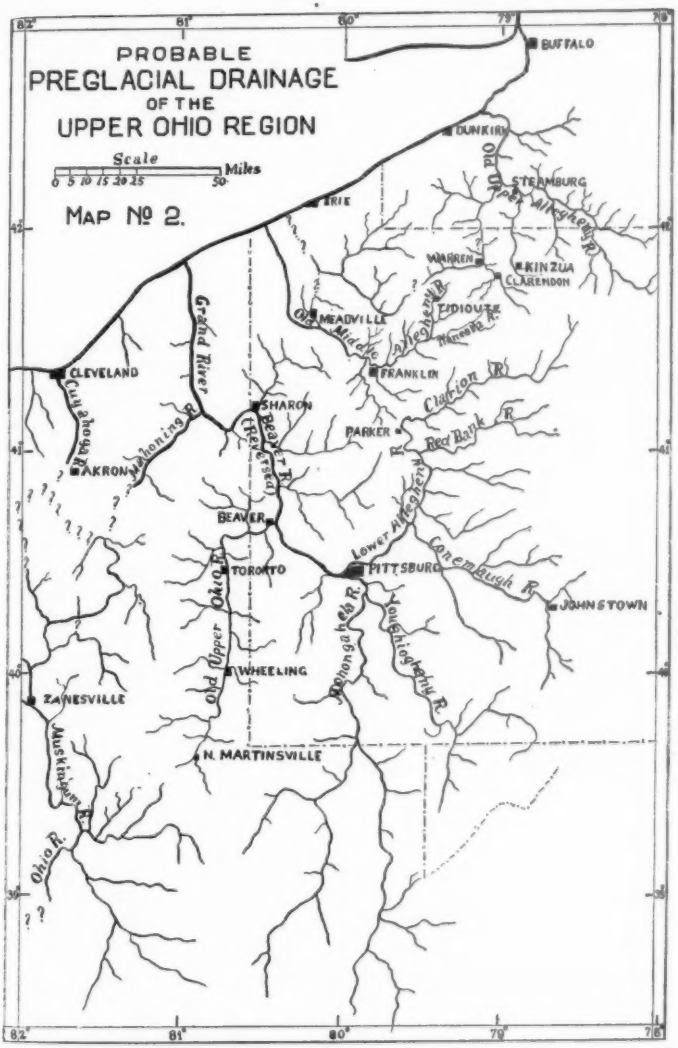
That the upper Tionesta-Conewango basin did not discharge southward along the present course of the Allegheny seems evident from a constriction of the valley which sets in near Thompson's station, about twelve miles below Warren, as indicated by Mr. Carll who located the old col at that point. The narrowness of the Allegheny at Thompson's as well as for some miles below, is in striking contrast with the portion of the Allegheny valley between Thompson's and Warren, and also that of the main tributaries (the Brokenstraw and Conewango), the width being scarcely one-third of a mile while the width of the valleys named is nearly a mile. In both situations the bluffs are mainly of soft easily erodible strata, the hard subcarboniferous conglomerate which farther down the Allegheny is an important factor in the valley bluffs being present here only in the highest parts of the bordering upland. Evidence of reversal is also shown by the valleys of small side streams. Below the supposed col these have not been so broadly opened to the level of the Allegheny as they have above and the streams descend near their mouths through narrow trenches fully 100 feet in depth. It would appear, therefore, that the col could not have stood less than 100 feet above the present river bed at Thompson's, or 1220 feet A. T. This view is confirmed by remnants of the old rock floor preserved in an occasional rock shelf beneath early glacial gravels. At Tidioute, some eight miles below the supposed col, the lowest discovered limit of erosion prior to the deposition of these gravels is about seventy feet above the present stream, whereas at Warren, fifteen miles above the col, the erosion seems to have reached a level even lower than that of the present stream.

It is probable that the line of discharge was through the Conewango (reversed), though a deeply filled broad valley connecting Brokenstraw creek with Oil creek along the line of



the Dunkirk, Allegheny Valley and Pittsburg railway between Garland and Titusville, Pennsylvania, raises the question whether the discharge may not have been in that direction.

By reference to profiles A and C, fig. 1, it will be seen that the rock floor is nearly level for a few miles north from Warren, while both to the north and south from this there is a



decided northward descent. This singular feature may perhaps be due to a recession of the Thompson col through valley excavation, as suggested by Mr. Carll (Penn. Second Geol. Survey, Rept. IIII, p. 311), and the formation of a pseudo col north of Warren at a point where excavation and consequent

recession were interrupted by a later filling of glacial gravel. An apparent objection to this is found in the fact that there is no appreciable decline in the rock floor from Warren to the Thompson col. This level condition, however, may perhaps find its explanation in northward differential depression of a floor once sloping southward with a low gradient. In profile A, a broken line is introduced which has, at Warren, the altitude of the lowest rock shelf *covered by early gravel* and which perhaps represents the limit of preglacial erosion. This line would give to the rock floor a continuous northward descent.

The course of discharge was probably through the Conewango-Cattaraugus outlet of the upper section of the Allegheny, for there seems to be no direct northward outlet to Lake Erie from either the Chautauqua or Cassadaga valleys so deep as the Conewango-Cattaraugus outlet.

The Oil Creek Basin.—We need refer but briefly to this basin since it does not involve a section of the Allegheny but only a tributary, and since the evidence of reversal has been fully presented by Mr. Carll. The greater part of this basin drained northwestward through Muddy creek to the French creek valley near Cambridge, Pennsylvania. There is some uncertainty as to the course of the outlet from Cambridge, the data being insufficient to show whether it was direct to the Lake Erie basin along the deeply filled Conneautee creek valley or indirect along French creek valley past Meadville to the Conneaut outlet and thence northwest past Conneaut lake and through Conneaut creek valley to the lake basin. Mr. Carll thought it had the latter course because of doubt as to the existence of a deep channel connecting Conneautee and Elk creek valleys. That region is, however, so thickly covered with drift that there is no certainty as yet that a deep channel does not cross it. Furthermore there seem to be objections to the view that the old stream followed down French creek, there being a series of island-like hills in the midst of the valley below Venango, midway between Cambridge and Meadville. These suggest the possibility of an old col there. A decision cannot be reached until each valley is more thoroughly tested by borings.

The Middle Allegheny Basin.—This basin includes the lower portion of the Tionesta (below the old col near Barnsville P. O.), the Allegheny from the old col at Thompson's to near the mouth of the Clarion, and the lower part of French creek. Several lines of evidence unite in indicating that this district formerly discharged northwestward past Conneaut lake to the Lake Erie basin. Evidence in favor of the reversal is found in the narrowness of the Allegheny valley above the mouth of

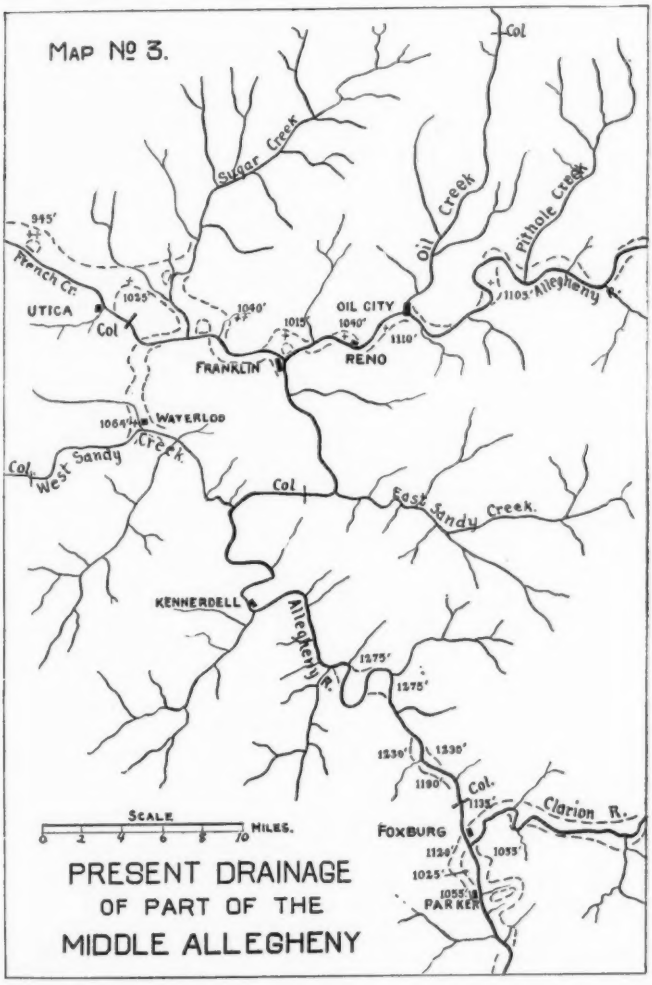
the Clarion as compared with the Clarion-Lower Allegheny valley. Evidence is also found in an elevated watershed which crosses the Allegheny immediately above the mouth of the Clarion. Further evidence is found in the rock shelves or old rock floors of the Allegheny and French creek valleys.

Taking up these lines of evidence in the order named, attention may be called to the presence of a broad base-plane or gradation-plane* a mile or more in average width which follows the lower Allegheny, standing about 200 feet above the present stream.† This broad gradation-plane follows up the Clarion but does not extend up the Allegheny above the mouth of the Clarion, the Allegheny having a narrow valley with precipitous bluffs reaching a height of nearly 400 feet above the stream. It seems necessary to suppose either that a disproportionately small gradation-plane with high cliff borders lay in this narrow gorge (having a breadth only one-third to one-half that of the Clarion and Allegheny gradation-plane), or that there has been a reversal of drainage by which a small stream that formerly flowed northwestward through this gorge to join the French creek outlet was reversed and its valley recut to fit the new and larger stream. We naturally look to differences in the hardness of strata for a possible explanation of the difference in the size of the valleys. On the supposition that there has been but little enlargement of the preglacial Allegheny through additions due to glacial agency we must explain the fact that a stream not less than three times as large as the Clarion excavated a valley only one-third to one-half as great. If the ice caused the addition of the two upper sections of the Allegheny, and not of the section under discussion, we must account for the fact that a drainage area about the size of that of the Clarion cut a valley but one-third to one-half as great. The strata along the narrow portions of the Allegheny from Franklin to the mouth of the Clarion, as well as for some distance above Franklin, are on the whole rather more resistant than are those in which the gradation-plane of the lower course of the Clarion was carved, there being in the former a considerable thickness of the subcarbon-

*For use of terms see Physiography in the University, W. M. Davis, Jour. of Geol., vol. ii, No. 1, p. 77. A *degradation* plane or profile (fluvial), results from erosion in excess of deposition, and is the common type. An *aggradation* plane or profile (Salisbury) results from deposition in excess of erosion, the plane being built up. A *graded* or *gradation* plane or profile (Gilbert), results from a balance between erosion and deposition, the work of the stream being expended in widening its valley. This is equivalent to a plane or profile of *equilibrium* (Davis), and to a rather strained application of *base-level* or *base-plane* (Powell). It is advocated by Gilbert and Davis because it avoids this strained use, is measurably convenient, and falls in with the preceding terms to form a symmetrical series.

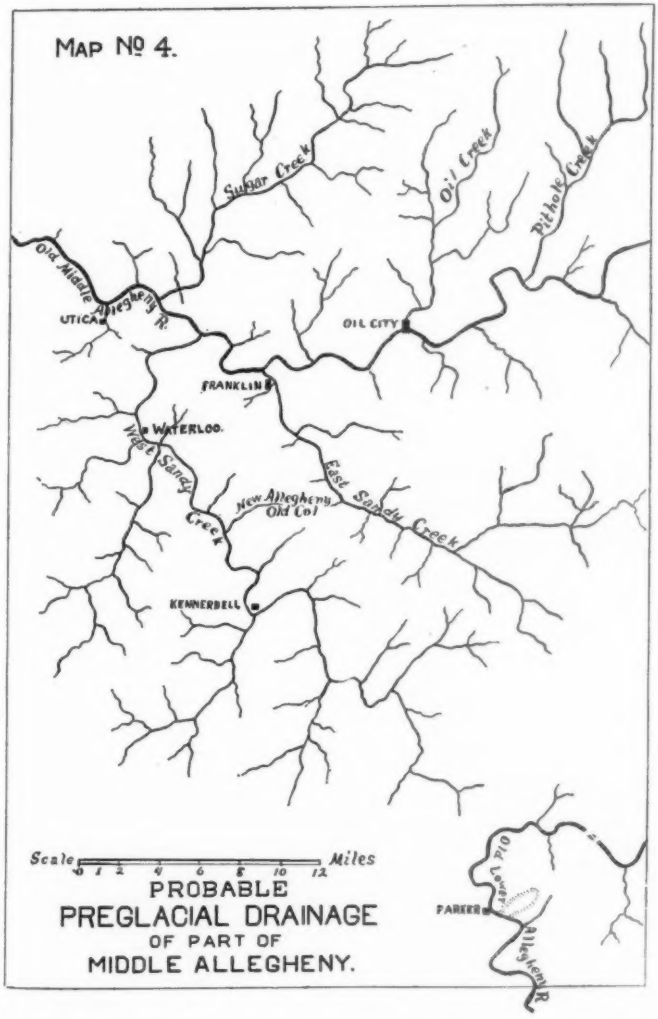
† Bull. U. S. Geol. Survey, No. 58, 1890, pp. 22–24.

iferous conglomerate (in places reaching as much as 75 feet), while on the latter there are more easily erodible coal-measure sandstones and shales. This greater hardness and resistance to erosion would naturally lessen the size of the valley. It



should also influence the gradient of the stream if it is an important factor. We turn, therefore, to the latter for light upon this question. In the portion of the Allegheny where

the hard subcarboniferous conglomerate appears, that is, from Cobham near the Thompson col to the Brady bend below the mouth of the Clarion, a distance of about 100 miles, the rock floor descends 2·7 feet per mile, fluctuating between 6·85 for a



few miles below Cobham, near where the stream is supposed to have taken its rise, to ·95 in the 18 miles immediately above

Franklin, where the stream is supposed to have been largest. In the portion between Franklin and the mouth of the Clarion the average fall is 2·6 feet, of which the greatest fall appears between Franklin and Kennerdell where a col is supposed to have been crossed (the fall there being 4·3 feet, while between Kennerdell and the mouth of the Clarion it is less than 1·4 feet). Passing now to the portion of the Allegheny between the Brady bend and Pittsburg, where excavation was in the softer strata, there is, in a distance of 70 miles, an average fall of about 2·3 feet per mile, or about ·4 feet less than in the portion where erosion was in the harder strata. The effect of rock resistance would seem, therefore, to be scarcely appreciable when measured by this method and hence inadequate to account for the disparity in the size of the valleys under discussion.

Furthermore, it is significant that the tributaries of the portion of the Allegheny above the mouth of the Clarion had not deepened their channels to levels in harmony with a gradation-plane as low as that of the Clarion. While they have normal gradients on their upper and middle courses, they descend by rapids and cascades to the present Allegheny. This is done from a height of about 400 feet, while the tributaries of the Clarion descend in this way from only about 200 feet. This seems to indicate that they have discharged until recently into a stream which had not reached so low a plane as that of the Clarion.

Turning now to the bordering uplands, we find a second line of evidence favoring reversal. Immediately above the junction with the Clarion, the Allegheny cuts through an elevated tract which to the eastward constitutes the divide between waters flowing north and northwest into the Allegheny and those flowing south into the Clarion, while, to the westward, it constitutes the divide between the northward and eastward flowing tributaries of the Allegheny, and the streams flowing south and west to the Beaver and Shenango (see map 4). The high divide is broken by only a narrow gap scarcely a half mile wide and 500 to 600 feet in depth where crossed by the Allegheny. The altitude and relief of this divide appears to be due to its relation to drainage systems rather than to axes of upheaval for its trend is in large part independent of such axes. That is to say, it constitutes a natural boundary between the middle Allegheny and the Clarion-Lower Allegheny drainage basins.

Before passing to the third line of evidence in support of reversal we should note that the portion of the present Allegheny between the supposed col at the mouth of the Clarion and the French creek outlet appears to have been made from

portions of two streams each flowing northwestward but separated by a divide below the mouth of the East Sandy creek. This view is supported, not only by a notable constriction there (to a width of scarcely 60 rods), but also by an abandoned valley leading northward from the bend of West Sandy creek at Waterloo to French creek valley just above the mouth of Sugar creek, which would afford a northward outlet for the western stream. The relationships of the present streams to this abandoned valley and to the supposed col may be seen by a comparison of maps 3 and 4. This comparison will also serve to show how natural the restored system is as compared with the disturbed and unnatural present system.

Turning next to the line of evidence found in the rock shelves and terraces, a general inspection of the French creek valley shows that there has been broader and deeper excavation than on the middle Allegheny. But inasmuch as the French creek valley lies within the glacial boundary, and its lower course nearly coincides with the direction of the ice flow, the question is naturally raised whether its greater size may not be due in the main to glacial excavation. An examination of the valley with this question in mind led to the discovery of old channels and ox-bow curves of pre glacial streams whose preservation is so complete as to furnish decisive evidence that glacial excavation has been of little consequence in determining the size of the valley.

On the stream which, as indicated above, seems to have led northward from the highland tract near the mouth of the Clarion past Waterloo to the present French creek valley, there are remnants of an old valley floor near the supposed divide at an altitude of 375–400 feet above the river, or 1275–1300 A. T., while at Waterloo in the abandoned valley which leads from Sandy creek northward to French creek, the rock floor is shown by several oil wells to have an altitude about 1060 feet A. T. This valley is filled with glacial gravel, apparently of early glacial age, and its rock floor has not suffered excavation since the gravel deposition. Its rock floor is the probable continuation of the elevated rock floor of the head waters and indicates a decline of somewhat more than 200 feet in 18–20 miles. This rate of fall would be natural in such a small stream descending from the elevated tableland and differs but little from the rate of fall in southern tributaries of the upper Allegheny of corresponding size, e. g., the fall on the Tuna, a similar stream, from De Golier, Pennsylvania, to the mouth of the stream, a distance of 14 miles, is 215 feet. (See Carll, Penn. Rept. III, p. 334.) At the north end of the abandoned valley, where it opens into French creek, rock shelves appear at an altitude of about 1040 feet A. T., which seem to mark the continuation of the old valley floor.

Turning now to the main stream of the supposed old middle Allegheny, we find that the col at Thompson's seems to have had a height of at least 1220 feet A. T. At Tidioute, eight miles below, early glacial gravels rest on a rock shelf (that represents the old river bottom), at 1160 feet A. T. At Reno, a similar shelf stands only 1040 feet A. T., while at Franklin, in an ox-bow filled with early glacial gravel, one boring reached rock at 1040 feet A. T., while another penetrated to 1015 feet A. T. without reaching rock. The gravel at these points rises to a level much above that of the terraces connected with the moraine of the later ice invasion and sustains such relations as to show clearly that it has suffered no disturbance since deposition. The shelves, therefore, antedate the gravel, and are remnants of an old river bottom. Following along the supposed outlet to the westward, there is an old meandering valley lying near the present French creek and, in part, coinciding with it. (See map 3.) On a small eastern tributary of this old valley three miles northwest of Franklin, wells, situated a mile or more back from the junction of the tributary with the old valley, strike a rock floor at about 1040 feet A. T., which is about as low as the rock floor found in one of the wells in the Franklin ox-bow, and is within 25 feet of the bottom of the other. These wells penetrate about 100 feet of drift of *early glacial age.* As they are back from the principal valley, the presumption is that the main channel is lower. Continuing northwestward along the valley to a point eight miles from the Allegheny, a well is found which reaches the rock floor at 1025 feet A. T., i. e., at a depth intermediate between the depths of the two wells in the abandoned ox-bow at Franklin. This well is situated near the southern edge of the valley, and can scarcely be supposed to have struck its deepest portion. Farther northwest, in an old ox-bow three miles north of Utica, similar in every way to the ox-bow at Franklin (see map 3), except that it lies within the limits of the later ice invasion, the floor is shown by one well to be 945 feet A. T. and by another 960 feet A. T., i. e., 70 feet and 55 feet, respectively, below the bottom of the lowest well in the Franklin ox-bow. Still farther northwestward on French creek at Cochranton, Buchanan, and Meadville, there are wells showing excavation to still greater depths; the first two not reaching the bottom at 915 and 800 feet A. T., respectively, and the last finding rock at 605 feet A. T. The depth of drift at this last point is not less than 475 feet, and the rock bottom is only 32 feet above Lake Erie. Meadville is only 28 miles from the Allegheny. To reach this depth on the present course of the Allegheny it must be followed 150 miles.

The evidence seems to us very strong that the ox-bow at Franklin, the old channel northeast of Utica, and the ox-bow north of Utica are remnants of the same old meandering stream leading northwesterly. The fact that the rock floor in the ox-bow north of Utica is 70 feet below the deepest determination of the old channel where it left the present Allegheny, renders it highly improbable, if not impossible, that it was formed by a stream discharging toward the Allegheny. It is even lower than the present rock bottom of the Allegheny, notwithstanding all the erosion the latter is believed to have suffered since the deposition of the early glacial gravels. It is highly probable, therefore, that we have, in these abandoned valleys, a continuation of the old middle Allegheny. An inspection of the general configuration of the old channel, as shown on map 3, will lend support to the force of these considerations.

A comparison of the old gradation-planes on the middle Allegheny with the like gradation-plane of the lower Allegheny at the mouth of the Clarion, brings out the significant fact that the rock bottom in the Franklin ox-bow stands about 40 feet *below* the rock bottom of the ox-bow above Parker, just below the mouth of the Clarion. *This is 40 miles distant down stream* (see fig. 4). If we compare the lowest point found on the old gradation-plane near Parker with the bottom of the deepest well in the Franklin ox-bow (which did not reach bottom), it is still 10 feet higher. If we compare their respective heights above the present river, the bottom of the Franklin ox-bow is not more than 35 feet, while that of Parker is 150 feet above the stream. Granting as probable that the old stream had a less fall than the present one, it still seems impracticable to refer the Franklin ox-bow and the gradation-planes and shelves associated with it, to the same stream that made those at and below the mouth of the Clarion at so much higher levels.

An additional point in evidence that the Allegheny has had its upper drainage basin enlarged by additions is found in a comparison of the size of the trench cut in the old fluvial floor of its lower course with that of the corresponding trench of the tributaries. For instance, on the Redbank river, which enters 22 miles below the Clarion, accurate data are obtainable, since the railway follows its valley for 70 miles and has a grade nearly coincident with the stream, and but a few feet (20–40) above it. The profile of this railway (see fig. 2), brings out the significant fact that the stream has a much more rapid fall in the lower 20 miles of its course than above that point, which is the reverse of the normal law of streams. The average fall for this 20 miles is nearly 12 feet per mile, while for the next 20 miles above, or even 50 miles above, the

average fall is less than two-thirds of this. In the upper portion, the present floor of the stream nearly corresponds with an old floor. In the lower portion, this old floor continues on to the mouth with a rate of descent a little less than that of the upper portion, following the normal law. The later stream has here, however, cut down 145 feet below the old floor. But this lessens rapidly up stream, and at 20 miles above the mouth, it is reduced to about 60 feet.*

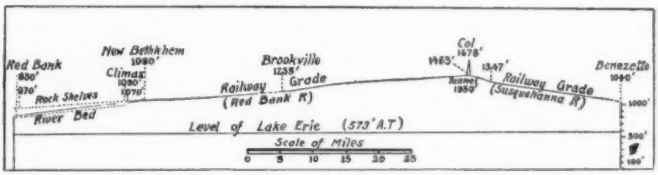


FIG. 2. Profile along a portion of the Low Grade Division of the Allegheny Valley Railway (so named because of the low altitude at which it crosses the Allegheny mountains). It serves to show the increase in the rate of fall of Redbank river in its lower 20 miles, a feature due to the deeper trenching of that portion. The profile also serves to show the extreme narrowness of the col which separates the Redbank and Susquehanna systems, the tunnel beneath the col being but 1950 feet in length.

It appears quite evident from these facts that there has been an abnormal deepening of the Allegheny since the formation of the old floor, and that this has been so recent that it has, as yet, only made itself seriously felt upon the gradient of the Redbank in its lower 20 miles. Such an abnormal deepening is accounted for by the sudden enlargement of the drainage area to several times its previous size in consequence of the diversions of drainage previously discussed. We do not think a simple change in the altitude, or in the general slope of the region, would produce a result of precisely this nature. The main stream, of course, usually leads in rejuvenated excavation, but not in such a disproportionate degree as this nor in precisely this method.

An objection to the northwestward outlet may perhaps seem to be presented by the deposits of gravel which occur along the Allegheny valley between the mouth of French creek and the mouth of the Clarion. In several places, notably at the bends of the river at Brandon, at a point two miles below Brandon, at Kennerdell, at Black's (Winter Hill station), and at Emlenton, there are deposits on the face of the gorge extending from near the river's edge up to heights of 200–300

* Compare statement of Prof. I. C. White respecting the relative altitude of water deposits on the upper and lower courses of the Conemaugh, Youghiogheny and Cheat rivers, this Journal, November, 1887, p. 378.

feet or more above the stream. The occurrence of this gravel at low levels cannot be accounted for by creeping or land slides, since, in some places, notably at Kennerdell and two miles below Brandon, the gravels show clearly by their situation and bedding that they have not been disturbed since the stream deposited them. We are not, however, reduced to the one interpretation that the valley had been opened to its present depth and had southward drainage before the beginning of the glacial period. These gravels are in every observed case situated on sloping points on the inner curves of sharp bends in the river. At such places a stream works outward as well as downward, there being erosion on the outer curve and liability to deposition on the inner curve. It is to be expected, therefore, on the hypothesis that the stream has greatly deepened its channel since the ice invasion, that such deposits should be present, and these deposits do not, we think, necessarily oppose the hypothesis of former northwestward drainage, nor that of great erosion since the beginning of the glacial period.

The Lower Allegheny-Monongahela-Upper Ohio Basin.—Dr. P. Max Foshay, taking up a suggestion of Dr. J. W. Spencer,* has brought out evidence in support of the hypothesis that the Lower Allegheny and Monongahela drainage basins, together with a considerable portion of the upper Ohio, formerly discharged through the Beaver, Mahoning, and Grand river valleys to the Lake Erie basin.† He first called attention to evidence furnished by the elevated base-plane, or gradation-plane (200–300 feet above the present beds). He noted the great breadth of this plane on the Beaver, its apparent northward slope and the occurrence on its rock surface of pot holes which appear to have been formed by a north-flowing stream. This gradation-plane was traced no farther than Wampum, some fifteen miles from the mouth of the Beaver, where glacial deposits become so thick as to make further tracing difficult, but it was thought by him to have followed a direct course along the Mahoning to the Grand river basin.

In the studies of the past season, an attempt was made to trace the old gradation-plane of the Beaver from the point where Dr. Foshay left it to the Grand river basin. It was found that the Mahoning route, which is the most direct one, was not a probable line of discharge since the valley, as indicated more fully below, is very narrow in the vicinity of the Ohio-Pennsylvania state line, and bears evidence of a reversal of drainage. Nothing was found to oppose the view that the

* Penn. Second Geol. Survey, QQQQ, 1881, pp. 385, 409.
† This Journal, Nov., 1890.

old stream may have followed the lower part of the Shenango in reverse as far north as Sharon, Pennsylvania (passing perhaps through an abandoned valley, which leads across from the Mahoning to the Shenango, between Edenburg and Harbor Bridge). From Sharon, it may have turned westward to the Mahoning river at Youngstown, through a lowland tract occupied by the Erie and the L. S. & M. S. railways, since at Hubbard, Ohio, situated in the midst of this lowland, the rock floor is found to be but 790 feet A. T., or about 100 feet lower than the rock surface of the gradation-plane on the Beaver, at Wampum (about 40 miles south). The valley is broader than that occupied by the Mahoning, a feature which lends support to this route in preference to the direct one through the latter valley suggested by Spencer and Foshay.

The slope of the uplands lends some support to the theory of northward discharge, there being a decline of about 200 feet between the mouth of the Beaver and Sharon, and an additional decline of 50 feet to the border of the Grand river basin (see profile B, fig. 3).

3.

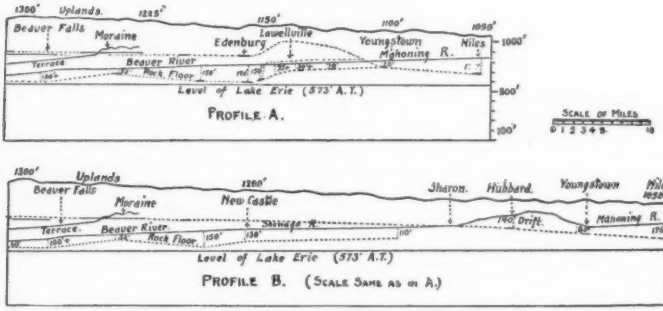


FIG. 3. *Profile A* shows the old gradation-plane, the buried channels, and the present drainage of the Mahoning-Beaver system, between Niles, Ohio, and Beaver, Pennsylvania, together with the old col at Lowellville. In this and in profile B well sections are represented by vertical lines beneath the line of the present stream.

Profile B shows the old gradation-plane, the buried channels, and the present drainage of the supposed old outlet of the upper Ohio between Beaver, Pennsylvania, and Niles, Ohio.

The hypothesis of northward drainage on the upper Ohio derives support from the narrowness of the portion of its present valley along that part of West Virginia known as the "Panhandle." The narrowness of this portion of the valley has been a matter of remark by nearly all glacialists who have traversed the region, the width being scarcely one-half as great as on the portion of the Ohio between Pittsburg and the

mouth of the Beaver, or on the supposed outlet along the Beaver and lower Shenango. It is further supported by peculiarities in the drainage of the upper Ohio. Nearly all the tributaries entering the valley above New Martinsville, West Virginia, point northward, i. e. up stream, as the river now flows, while those below point down stream. The suggestion of an old water parting here occurred to the senior writer in a trip up the Ohio some years ago, and we learn that the same thought has occurred to Mr. Carll.

The junior writer gave some attention the past season to the high-level terraces between Wheeling, West Virginia, and the mouth of the Beaver. Many remnants of these terraces occur in recesses of the valley and on the lower courses of tributaries.

At first inspection the shelves do not seem to fall into obvious systems, and as our work on them is not yet complete we shall express no final judgment here. A preliminary study of the data, however, seems to throw the higher shelves into a very interesting and significant two-fold system.

Starting with the well developed high terraces at the mouth of the Beaver where the rock shelf is about 880 feet A. T. and the gravel terrace 935 feet, we find, six miles below, a rock shelf at 940 feet A. T. covered with early glacial gravel; another 12 miles farther down at East Liverpool, Ohio, at 950 feet; another at Wellsville, Ohio at about the same height; another shelf six miles below Wellsville at Tomlinson Run, at about 1000 feet (without glacial gravel); another north of New Cumberland, West Virginia (two miles farther), at about 985 feet covered with scattering pebbles, but no Canadian pebbles found; another at Toronto, Ohio (four miles farther south), has about 10 feet of glacial gravel on a shelf 950 feet A. T. plainly occupying the deepened portion of an old river bend. This is the farthest point to which the high level glacial gravels were traced. Although slightly higher than at the mouth of the Beaver they are 15 feet lower at Toronto than at Pittsburg, a feature which indicates that they have suffered reduction at Beaver. About five miles below Toronto, at Holliday Cove, West Virginia, there is an interesting branch of the deeper channel cutting off an island upland, as it were, which is filled with late glacial gravels. Across this island there passes an old channel of Harmon's creek (an eastern tributary), which stands at 350 feet above the river, or 990 feet A. T. Opposite Steubenville, Ohio (three miles below), a shelf stands at about 1000 feet; another on a western tributary at Mingo Junction, Ohio (two miles farther), at about the same height; another at Wellsburg, West Virginia (four miles below), is slightly higher (1005 feet A. T.). This is well devel-

oped along Buffalo creek and also north of its mouth. At Beech Bottom, West Virginia (three miles below Wellsburg), is a broad shelf at 935 feet; at Portland, Ohio (four miles farther), there are two notable shelves, the higher at 1085 feet and the lower at 950 feet; opposite Wheeling, West Virginia (eight miles below Portland), there is a notable terrace at 930 feet and another at 990 feet, while back of Wheeling a plain sweeps about the high hills at about 1100 feet.

Here there seems irregularity and want of system, but if the 930 feet terrace at Wheeling, the 950 feet terrace at Portland, and the 935 feet terrace at Beech Bottom be connected with the 950 feet terrace at Toronto where the glacial gravels cease, and these be interpreted as remnants of the trench cut across the old divide after the supposed reversal and while the gravels above were being accumulated, and if all the rest be interpreted as remnants of the floor of the old system running northward to join the lower Allegheny-Monongahela-Beaver system, the whole seems to fall into tolerable harmony. The terraces referred to the trench below Toronto are generally swept clean of debris and so accord with the hypothesis. The breadth of the corresponding gradation-plane at the mouths of tributaries seems larger than might be expected under this hypothesis unless we make the first glacial epoch long, and this is, perhaps, against the hypothesis. We leave the question open for the present.

Dr. Foshay also called attention to the low altitude of the present *rock floor* of the valley along the supposed outlet (there being oil well records showing lower rock bottom on the Mahoning than at the mouth of the Beaver), and he maintained that northward discharge was continued until the streams had reached this low level. In opposition to this view, it has since been determined by Mr. R. R. Hice that the rock floor does not have a regular descent northward from the mouth of the Beaver, but stands 60 to 70 feet higher in the gorge near the mouth of the Connoquennessing than at the mouth of the Beaver, and about 90 feet higher than at Edenburg, about 15 miles up stream. His data seem complete, as the piers of a railway bridge were built upon the rock floor and so distributed as to test the middle as well as borders of the valley. So far as collected, the data from well sections, both on the Mahoning and Shenango, oppose the view that the low rock floor near Edenburg was occupied by a stream which discharged into the Lake Erie basin (see sections A and B, fig. 3). The Mahoning, just above the very deeply excavated portion, has a narrow valley 80 to 100 rods wide, or scarcely one-half of its width where deeply excavated. From the borders of this narrow portion, tributary streams descend over cascades from levels of 100 to 200 feet above the river. A

study of the old and the present rock floors on these tributaries leads us to locate an old col near Lowellville, Ohio, just west of the State line, the altitude of which appears to have been at least 1025 feet A. T. This has been trenched to a depth of about 200 feet, and has a width at bottom of from 80 to 100 rods in the narrowest portions. Within this narrow portion, there is a still narrower trench, in places restricted to the limits of the present river channel, a width of but 15 to 20 rods. (The greater part of the valley is floored with rock at a level 20 feet or so above the present stream, as shown in section A, fig. 3). In this inner trench, no borings have reached the depth of those near the mouth of the Mahoning before entering rock. Two borings, one at Hazleton and the other a mile east of Struthers, Ohio, enter rock at only 80 and 70 feet, respectively, below the present stream. These are 140 to 150 feet *above* the low rock floor, near Edenburg, only nine miles below Struthers. The inner very narrow trench is obviously a minor feature in the history of the valley. The main work, after reversal, was the cutting of a trench across the old divide about 200 feet deep and 80 to 100 rods wide in its narrowest parts. The most interesting feature of the lower part of the valley is the sudden descent it makes just above Edenburg. Here the buried floor falls 165 feet in a half mile, as shown by four wells.* The declivity may even be more precipitous as the wells are not so situated as to limit the space occupied in the descent more closely. A mile further down the stream, a well penetrates 200 feet of drift, about 190 feet being below the present river. Farther down stream, so far as there is evidence, the rock floor rises, and, in the Beaver gorge near the mouth of the Connoquennessing, is within 52 feet of the bottom of the present river, or 90 feet above the deepest portion near Edenburg. Profile A, fig. 3, shows this diagrammatically. This profile strongly suggests a fall or steep cascade at Edenburg with a pool below. And this suggestion falls in very happily with the indicated history of the region, which seems to be as follows:

Before the ice invasion forced the waters of the upper portion of the Grand river basin across the divide at Lowellville thereby forming the Mahoning river, a tributary about three miles long descended to the main valley now occupied by the Shenango-Beaver river (then probably occupied by the northward flowing Monongahela-Beaver system). This small tributary we think joined the main valley at the horizon of the upper terrace level. At any rate, the drainage of the three-mile valley would be quite incompetent to develop a deep pool.

* We are indebted to Mr. W. H. Raub of Edenburg for these data.

But when the waters of the upper Grand river basin were forced over the col in large volume and descended the steep slope of the little valley (from about 1025 feet A. T., to about 850 feet A. T., in three miles), deep scouring at the mouth would naturally result and the formation of cascades or falls would readily follow. These would work up stream as the erosion progressed. They appear to have reached a point just above Edenburg when a later incursion of the ice stopped the process and filled the deep valley with debris. After episodes that need not be noted here, the stream assumed its present horizon.

Passing by several minor features of interest, the phenomena seem to clearly point (1) to very notable erosion (200 to 250 feet), after the drainage was reversed by the ice, and (2) to the filling of the trench so cut 200 feet or more with drift by a later ice incursion, and (3) to only a very moderate erosion since this late filling. This valley which was cut after the early reversal bears on its sides morainic debris, and also at some points in the bottom of the stream. The stream has not here cut into the later drift to exceed 75 feet.

The profile along the Shenango river shows phenomena in harmony with these. Only that portion of the pool which lies below the junction of the two streams appears as a notable phenomenon. It shoals rapidly to the north as though the Shenango merely bevelled the up-stream edge of the Mahoning pool.

The formation of the pool was favored by the softness of the rock in this portion of the valley and the hardness of the Homewood sandstone near the mouth of the Connoquenessing.

This reference of the puzzling phenomena presented by the closed basin in the bottom of the Mahoning and Shenango valleys at their junction to the exceptional scouring action of the Mahoning consequent upon its precipitous descent from the Lowellville col when forced over it by the invading ice seems to fit the phenomena much better than previous hypotheses,* though the other hypotheses may find partial application here and more full application elsewhere in the region.

So far as these observations go, they are in consonance with the hypothesis of northward discharge advocated by Dr. Foshay, differing from it only in suggesting that the probable watershed may be some 50 miles further south on the Ohio, and in restricting the application of the hypothesis to the ele-

*The scouring of streams of ice, I. C. White. Second Penn. Geol. Survey, Q, p. 17, QQ. pp. 16–20, Q*J*, p. 20. Q*J*, pp. 37–38, and elsewhere in these reports. Ice and under-ice currents, J. F. Carll. Second Penn Geol. Survey, III, p. 362 (Footnote). IIII, pp. 234–5 (Footnote). Northward differential uplift, P. Max Foshay. This Journal, Nov., 1890, p. 400. Northward differential depression, ice, and subglacial waters, Frank Leverett. This Journal, Sept., 1891, pp. 208–9.

vated gradation-plane, or to the upper part of the trench within it. They seem to show that it is inapplicable to the lower part.

Other changes of drainage in the Ohio Basin. — Though beyond the field of this paper, we call attention, by way of suggestion, to possible changes of drainage in portions of the Ohio basin further west. The present divide between the Lake Erie and Ohio basins in eastern Ohio is apparently much farther north than the preglacial divide, there being a series of deeply filled valleys crossing the watershed and connecting with the Mahoning and Cuyahoga valleys. A well near this watershed, about six miles southwest of Akron, penetrated 400 feet of drift and struck rock not far from the level of the surface of Lake Erie, though distant 35 miles from the present shore of the lake. Several wells a few miles farther west, in the vicinity of Sterling, penetrate about as great an amount of drift and enter rock at the same low level. How much territory was thus drained to the Lake Erie basin has not been determined. The size of the Cuyahoga valley and of the upper part of the Mahoning warrants the presumption that it was a large territory. The relation of these drainage systems to the present watershed, and the lines of possible connection across the watershed, are shown, in part, on map 2.

We would also add that the small size of the lower Ohio valley is suggestive of great enlargement of drainage area within a recent period.

The suggestion has been entertained by several geologists, notably Professor J. F. James,* that the Ohio river formerly departed from its present course just above Cincinnati and followed Mill Creek valley to Hamilton, and thence the Great Miami valley to its junction with the present Ohio, and that it was forced from this course by the ice invasion, and caused to cut the trench which it now occupies at and below Cincinnati. This hypothesis is to be carefully distinguished from that of the Cincinnati ice dam, with which it is in ill accord since the Cincinnati trench could not have been dammed until it was formed, and, by hypothesis, it was only formed after the ice forced the river out of the Mill Creek channel.

It has long been known that the present channel of the Ohio, at Louisville, Kentucky, is recent. Its present location seems to be the result of valley filling during the later glacial stages.

Summary.—Summing up the preceding, it appears that the evidence is very strong that the two uppermost sections of the Allegheny basin, including also Oil Creek basin, formerly dis-

* Journal Cincinnati Soc. Nat. Hist., 1888, pp. 96–101.

charged northwesterly; that the evidence relative to the middle Allegheny makes it very probable that this also discharged northwesterly; that the evidence relative to the lower Allegheny and the upper section of the Ohio river also favors a northerly discharge, but is, as yet, too incomplete to justify a firm opinion.

Whether this weighing of the evidence is entirely correct or not, it is manifest that the preglacial erosion of these sections must be determined severally and independently if any safe conclusions are to be drawn. If they were separate basins, the depth of erosion of one does not determine that of the others, which were in no way perhaps directly connected with it. There would be a certain harmony, so far as like conditions prevailed, and the argument of analogy would have a proper application. In applying it, however, it is necessary to observe that the united sections were unlike in size, in direction, and in distance from the major basins into which they emptied. More particularly must it be noted that the united parts represent different fractions of their systems. Some are headwater sections, some body sections; and these have each their characteristic differences.

A few of the salient features of the old fluvial floors are all that space will permit here.

Old Fluvial Floors.

The old fluvial floor of the uppermost section finds its lowest point, on the line of the present Allegheny, at Steamburg, where it is about 1050 feet A. T. From this point, the old floor rises both up stream and down stream. Going up stream, the rock floor rises so as to become the bottom of the present stream only far up towards the head-waters, in Potter county, Pennsylvania. Going down stream, it rises so as to come near the surface at Kinzua, where the old col was cut across. The present floor here stands at about 1170 feet A. T. The old floor was considerably higher, but we have little data for an estimate of how much.

In the second of the united sections, we have, in the track of the Allegheny, only a short segment crossing the upper part of the old basin. The old floor appears to drop down from the old col at Kinzua to 1150 feet A. T., and possibly to 1100 feet, and then to rise toward the old col at Thompson's reaching about 1220 feet A. T., as well as we can estimate it, —possibly more. The lowest point of this segment, it will be seen, is 50–100 feet higher than the lowest point in the upper section. It is more than a hundred feet higher than the lowest point in the adjoining section to the south, and about 100

feet above the old floor at the mouth of the Clarion. It is, therefore, the highest of the united segments in the track of the Allegheny and most nearly coincides with the present river bed, which lies above the old floor in the upper section and below it in the lower sections, as we read the phenomena. On the middle Allegheny, or French Creek section, the old floor descends from the col at Thompson's to the ox-bow at Franklin where it stands at less than 1015 feet A. T. From this, the floor of the old east Sandy creek rises rapidly to the col between it and the west Sandy creek, where it descends rapidly to the latter, and then ascends it to the col near the mouth of the Clarion, which has an estimated altitude 1300 feet A. T. From this there was a rapid descent to the old well-developed floor at the mouth of the Clarion, at about 1050 feet A. T. Thence there is a long very gradual descent to Pittsburgh, and thence to the mouth of the Beaver, and probably onward northwesterly to the old Erie basin.

The above represent our interpretations, based upon present data, of the preglacial condition of the track selected by the Allegheny under the compulsion of the ice. It will doubtless require some modifications in detail, at least.

Into the small upper segments of the united basins, the glacial waters, issuing from the edge of the ice that here lay close to the track of the Allegheny, poured great quantities of glacial wash and filled them to irregular heights according to the volume of the feeding and the capacity of the valleys. The present stream, therefore, runs relatively high on these accumulations, and has not reached even the old floors in the axes of the two uppermost sections, if we interpret aright. But in the Lower Allegheny-Monongahela-Ohio section, we understand it to lie far below the old floor as has been urged elsewhere.*

4.

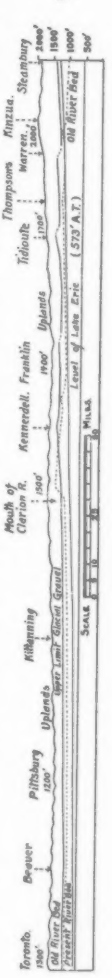


FIG. 4. Profile along the present Allegheny and Ohio rivers from Steamburg, New York, to Toronto, Ohio, representing the upper limit of glacial gravel, the gradation-planes, the cols and the present stream bed, also the general level of the uplands. The gradation-planes and cols are indicated by broken lines, the other planes by continuous lines. Attention is called to the building up of the glacial gravels to great heights at points where contributions were made from the ice sheet, and to the regular slope in the long stretch between the mouth of the Clarion and the mouth of the Beaver where no contributions of glacial gravel were made by tributary streams.

* H. M. Chance, Penn. Sec. Geol. Survey, Rept. VV, 1880, pp. 17–20. T. C. Chamberlin, U. S. Geol. Survey, Bull. 58, 1890, pp. 24–37.

Before pursuing the gravel depositions further, a word needs to be said about the glacial formations.

The Drift.

The general nature of the drift border of this region is so well known as to need but a passing word. It stretches along the northwestern rim of the present Allegheny basin, encroaching considerably upon it. It consists of two important factors, the more obtrusive of which is a group of terminal moraines that, to the southwest and northeast, deploy as separate and independent moraines, but are here so coalescent as to render their individual recognition difficult. It is helpful to bear in mind that we are not dealing with a single terminal moraine, but with a group, and that the more protruding moraine in one part is not necessarily the same as in another. We shall have, however, no occasion to dwell upon this distinction.

Outside of this group of terminal moraines, there is an attenuated drift whose thinness is probably due partly to original deposition and partly to subsequent wastage. To us, it seems demonstrably much older than the terminal moraines and the drift sheets back of them. *Associated with this attenuated drift, and springing from it, there are trains of gravel.* This important fact appears not to have been previously observed. Their connection with it seems to be essentially the same as that of the overwash and outwash drifts that are so common and significant dependencies of the distinct terminal moraines. These trains of gravel have, in several instances, been traced to their heads and found to connect themselves definitely with this attenuated border drift at levels much higher than the junction of the moraine-headed terraces with their drift sheets. For example, at the headwaters of Tidioute creek (some seven or eight miles north from the city of Tidioute), there is found a distinct overwash gravel deposit at the outer edge of the old drift at an altitude of 1700 feet A. T., while just above Tidioute in the Allegheny valley the early gravels attain a height of 1420 feet A. T., or 330 feet above the present level of the river. This great valley filling was probably from a tongue of ice thrust into the Allegheny below Irvineton as well as from contributions from the tributary, Tidioute creek.

On one of the headwaters of Pit Hole creek, at Pleasantville, similar gravels attain a depth of 80 feet and have an altitude of over 1600 feet A. T. Unassorted drift occurs in immediate connection with these up to a height of 1725 feet (see Carll, Penn. Rept. I, 1875). Similar gravels occur

on the headwaters of West Hickory creek situated between the above streams. Occasional remnants of gravel deposits on the slopes of the lower courses of these valleys at heights of 200 feet or more above the present creek bottom, together with the fact of an open valley to the Allegheny, at least suggest the view, if they do not demonstrate it, that these gravel trains were connected with the upper terrace gravels of the Allegheny.

At Clarendon, there seems ground for believing that the old ice border sent a tongue into the mouth of the old Tionesta valley, since it left bowlders on the opposite side of the Allegheny at altitudes 300 feet higher, and the glacial waters built up, with an abrupt north border, the unusual thickness of glacial debris which constitutes the head of the gravel train that follows the modern Tionesta valley. The whole aspect of the deposit is that of a glacial gravel train heading on the edge of the ice. It has the extraordinary height (for a valley train), of 1500 feet A. T. We seem to have, therefore, in this, and in the phenomena on Tidioute, Pit Hole and Hickory creeks, four of the points of origin of the high-level gravel terraces about to be considered. They seem to constitute connecting links between the high terrace gravels and the attenuated drift.

Terraces.

From what has already been said respecting the drift border and reversals of drainage, the terrace systems, to which we now turn, would naturally be expected to present much complexity of detail, and yet show general systems corresponding to the leading drainage events and glacial incursions. It will, therefore, be convenient to consider the more pronounced systems of terraces and then give so much attention as time may permit to minor phases.

Whatever more there may be, an uppermost and lowermost series of gravel terraces are well characterized.

The Upper Gravel Terraces.—The upper series of terraces are well developed from the vicinity of Warren, Pennsylvania, to Toronto, Ohio, a distance of 250 miles. They are quite varying in altitude, and in the depth of gravel, on the upper stretches of the Allegheny, where their development was notably influenced by feeders from the adjacent edge of the ice; but in the portion of the valley outside of the immediate influence of the ice edge, the series developed into much regularity. The summit altitudes in the upper irregular portion reach from 1200 to 1500 feet A. T. In the lower and more regular portion, the summit heights reach about 1135 feet near the mouth of the Clarion, thence descending to

about 950 feet in a distance of 140 miles. They have been traced down to Toronto, Ohio, where Canadian gravel occurs at the height last named.

The average thickness of the gravel in this more regular portion is found by combining ten excellent sections to be 83 feet; the maximum thickness being 110 feet and the minimum 55 feet. This is about double the thickness heretofore given by the senior writer.

Below this higher system, thin sheets of gravel occur on the slopes of the valley walls, which might be thought, perhaps, to extend the sections, but which we set aside for consideration later, as they do not seem to us to certainly belong to this series.

In the irregular portion, several points of special feeding are recognizable. At Steamburg, New York, the high terraces slope rather rapidly down the stream, the rate being ten feet per mile. They also slope downward in the opposite direction, i. e., up the stream. As this is also in the portion of the valley whose rock floor descends northward, the drift reaches the great depth of 400 feet. It thins out, however, to a few feet down the river near Kinzua.

Besides the great accumulations at Clarendon, already mentioned, there is another special thickening near Reno and Oil City where depths from 100 to 150 feet occur. These are probably referable to the near or immediate presence of the ice edge itself, for the occurrence of foreign drift on the highlands east of Brandon at 1400 feet A. T., suggests the proba bility that the ice edge crossed the river there and probably lay near it all the way between this point and Clarendon (see map 1).

Lower Terraces.—Passing for the moment over intermediate phenomena, we find low in the valleys a series of terraces which conform in general to the slope of the present stream, and usually do not rise more than 50 feet above it, though exceeding this at points of special feeding, as the mouth of the Beaver, where the unusual height of 130 feet is attained. Traced up stream, these terraces are found to head on the outer slopes of the system of terminal moraines before mentioned, at the points where these cross the respective tributaries. The terrace planes graduate into the overwash planes of the moraines and their material graduates into the morainic material itself in a perfectly clear and characteristic way, which leaves no room for doubt respecting their origin. This connection may be seen near Steamburg in the Cool Spring creek valley, near Russellburg on the Conewango, near Chandler's valley on Jackson Run, near Wrightsville on the Little Brokenstraw, near Horn's Siding on Big Brokenstraw, near

Hydetown on Oil Creek, near Coopertown on Sugar creek, near Utica on French creek, where, however, the connection is not very well displayed, near Raymilton on Sandy creek, above Homewood on Beaver creek, near Gallilee on Little Beaver creek, and near New Lisbon in another valley of the Little Beaver. Besides these twelve localities, at which the relationship of this low system of terraces to the moraines may be seen demonstratively, there are subordinate trains of gravel that make still more certain, if possible, the relationship.

All of these headings of the terraces are much lower than the upper terraces at points nearest to them. In the upper part of the basin, the higher terraces, even in the valleys, head 125 to 200 feet above the heads of the terraces of the lower system. If we compare with these the overwash trains on Tidioute and on Pit Hole creeks, which we interpret as being genetically the same. the difference in altitude is 350–400 feet (see section B, fig. 1). If we compare the head of the high-level gravels of Clarendon with the head of the low-level terrace at Russellburg, which is nearest to it and on the same ice-course, being only thirteen miles distant, the difference in the altitude is 210 feet (see section A, fig. 1). *From this it appears to us perfectly certain that the high-level terraces had no connection with the morainic overwash, but that, after the high-level gravel planes were formed, they were trenched to levels below the horizon of the lower terraces (presumably to the present rock bottom); otherwise, the lower terraces could not have been formed. The two systems are, therefore, separated in time by the interval required for this erosion.*

Thus far we think all careful students of the region must go with us, whatever they may think respecting the time required for the erosion, or regarding the kind of material removed.

Intermediate Phenomena.—The pronounced characters and the wide separation in time of the higher and lower systems of terraces being thus definitely determinate, we may turn to intermediate phenomena that may be less clear in their genesis and import. Between the base of the undisputed high-level gravels and the summit of the low-level systems, gravel is found at numerous points on the sides of the Allegheny trench. This gravel is commonly found on sloping points in the inner bends of the river and in other localities where, in cutting down its valley, the river would be likely to leave remnants of gravels, if they were there before, or would permit their lodgment in the process of sinking its bed, if not there before. Herein lies the radical difficulty of their interpretation. A winding stream, which is cutting down its bed at a moderate rate, tends to extend its meanders as well as deepen its floor, and so it cuts outwards as well as downwards

on the convexities of its bed and is disposed to permit the lodgment of material on its concave side where the tendency of the stream is to recede. Now, the Allegheny during the whole progress of its descent from the level of the high terraces to its present position, was undoubtedly a gravel-bearing stream. It was not only engaged in the process of removal of the gravel along its own immediate course, but was receiving very much that was washed in from the drift region adjacent, so that a certain amount of lodgment of transported material may be assumed to have been inevitable. This is dependent upon the same principle of action that would permit the retention of gravels, in such situations, if they had been previously deposited within the trench. As the gravels on the slopes are usually thin sheets or patches, we have not found decisive evidence, in themselves, as to whether they are remnants of earlier gravels, or incidents of degradation. We have searched industriously for evidence that should be decisive on this point. Such evidence should be found in abandoned segments of the old valley, if it had been deeply excavated before the deposit of the gravels and had subsequently been filled by these up to the summit of high gravels. These high gravels fill ox-bows and recessed shelves, and the stream which deposited them had, in many instances, alternative courses. This is notably true in the vicinity of Pittsburg. Here the old high plane of rock was extensively covered by the waters that deposited the gravels, as is shown by the presence of remnants. There are, in the eastern part of the city, four islands surrounded by broad channel-ways, among which the waters distributed glacial gravels in greater or less degree. Now, if the present deep Allegheny and Monongahela trenches had been cut previously to the filling in of the gravels, there is only a small chance that, after the gravel-depositing period, during which they were flowing 50 feet or more above the rock plane, they would have descended the second time on precisely the same lines. Between the several broad channels open to them, the possible combinations are 32 in number, and hence theoretically the chances of a combination repeating itself are one in 32. If it be objected that certain of the courses are more favorably situated than others, our answer is, first, why were these others then ever produced by the streams or occupied by glacial wash, and our second answer is, that, if this be true of certain combinations, it does not seem to us to be at all true of many others.

Besides this, along the Allegheny river above, and also along the Ohio river between Pittsburg and Toronto, to which point the high gravels containing Canadian pebbles have been traced, there are perhaps a score of ox-bows, deep recesses,

shelves, or available cols which would afford opportunities for the re-descending river to locate itself on other lines than its old track with all its meanders. When these possibilities are added to the preceding, it becomes exceedingly strange that, below the mouth of the Clarion, no abandoned channel is found which retains any old filling comparable in depth to the present trench. We find numerous old channels containing gravels ranging from 50 to a little over 100 feet that represent such old courses on the higher plane. This demonstrates the truthfulness of the principle here urged and shows its application to this particular field.

If any other proof of the tendency to take new courses in such situations were necessary, we might find it in the Rock River valley in Wisconsin, which was filled up south of the kettle moraine to a depth of from 350 to 400 feet with glacial wash. The stream twice within ten miles of the head of the filling cuts across rock spurs on the side of its old channel, and it makes a third cut within the next ten miles. On the Chippewa river, a similar number of rock cuts within a similar distance show the ready applicability of the principle. In these cases the old valley filling is retained in its integrity, and the fact of such filling is demonstrated.

So also in the middle Allegheny basin, along the line of drainage which we interpret as leading northwesterly to the Lake Erie basin, there are remnants of deeply filled abandoned channels; the present streams occupying, in part, newer rock cuts. At the mouth of the French creek, the old trenches reach within about 65 feet of the present rock floor of the Allegheny adjacent. The ox-bows and recesses retain here and there a full section of the old filling. These seem to us to emphasize the significance of the absence of similar sections reaching the bottom of the present valley below the mouth of the Clarion.

The strength of this negative evidence, in the lower Allegheny and the upper Ohio valley, is such that we are unprepared to accept the existence of thin sheets or patches of gravel on the slopes of the valley as establishing even a presumption that there was a trenching to anything like the present depth previous to the formation of the high terraces.

The improbability of the river re-establishing so completely its old course would not be applicable to a hypothesis which supposed the formation of the upper gravels on a high rock floor and the trenching of the valley afterwards to any depth below and a re-filling to a point *somewhat less* high than the summit of the earlier terrace plane for then it would be kept in its old course. Such an hypothesis would comport with two interglacial epochs, and if these remnants on the slopes

are really residues of a re-filled valley, they would seem to point to such an interpretation.

Low Rock Shelves.—Along the lower Allegheny, there stand a number of rock shelves at about 75–100 feet above the present river. These are of some considerable extent, occasionally reaching to a quarter of a mile in breadth. While not all at a common horizon, they are sufficiently near to be fairly correlated. There is but little drift on these. They may mean merely an incident in the cutting down of the valley, or they may signify the termination of an epoch of degradation, followed by a notable halt or possibly a re-filling. We have found little to suggest whether or not they have much significance and so pass them for the present with simple mention.

Interpretations.

The foregoing outline falls far short of properly setting forth the facts, and yet our time is far spent. We nevertheless beg a few words respecting interpretations. There is not time, however, for the discussion of these, and we shall content ourselves with a simple statement of such hypotheses as seem to have any justification in the phenomena now known, and with some comparisons respecting their import.

To us it seems clear that all hypotheses that do not explain the phenomena by simple glacial and fluvial action (with incidental ponding), are excluded by the very characteristics of the deposits themselves. We have reason to believe that this view will be no longer seriously contested.

We are also clear in the conviction that no hypothesis of continuity can explain the phenomena. They seem to demand unequivocally important stages of deposition separated by important stages of excavation.

Of hypotheses which fall within these limits, there are three which postulate a single pair of depositions and of erosions, and a fourth which postulates a triple alternation. The first group fall into accord with the twofold division of the adjacent drift, the attenuated drift, and the moraine-bordered drift. The third conforms to the threefold division of the drift, which is found in western Ohio and beyond. For convenience we shall state these hypotheses as applied to the more regular part of the system below the mouth of the Clarion. The qualifications for the more irregular upper portion may be readily derived from what we have said respecting those portions.

Hypothesis I.—This hypothesis is based upon a minimum expenditure of dynamic action, though this is an after thought and not the parent of the hypothesis. By this we mean that

the sum total of work done is the least that will apparently satisfy the phenomena, though more of the work is thrown within the limits of the glacial period than in the following hypotheses.

(1.) This hypothesis supposes that the Allegheny valley was cut down before the glacial period only to the observed base of the high-level sections of gravel, making such allowances for the incompleteness of observations as may be required.

(2.) The first known ice incursion, which reached the approximate limits at which thin drift and scattered bowlders are now found, gave origin to the high terrace gravels through its outflowing waters.

The amount of these gravels, even under this hypothesis, which minimizes them, seems extraordinary, when the thinness of the adjacent old drift is considered. This drift, however, has undoubtedly suffered large wastage as have the gravels themselves.

(3.) After the deposition of the gravels, the ice retired beyond the basin. So far as this problem is concerned, it matters little whether farther or not. Erosion followed, trenching the gravels not only, but the rock beneath to about the present depth.

(4.) Another ice invasion followed forming the adjacent terminal moraines and pouring its overwash gravels down through the trench previously cut, forming the lower gravel system.

(5.) Since the retreat of the ice beyond the limits of the basin, these gravels have been trenched by the present streams.

In this hypothesis, the amount of gravel deposition is minimized. The amount of interglacial erosion is made a maximum.

Hypothesis II.—This hypothesis supposes that (1) the river trenches of the region were cut to essentially their present depths before the glacial period, and (2) that, during the presence of the ice, the valleys were filled to the heights of the uppermost gravels—say 300 feet in round numbers. (3) Subsequently, these were trenched into nearly the present form. (4) Afterwards, the later incursion of the ice formed the adjacent terminal moraines and poured the overwash down the valleys forming the lower terrace planes. (5) These have since suffered trenching as postulated in the previous hypothesis.

This differs from the preceding hypothesis *in very greatly increasing the deposit of the first glacial epoch*, which we observed, even under the preceding hypothesis, was surprisingly large in comparison with the associated drift. It postulates the same volume of interglacial erosion, but this takes place in glacial gravels, instead of part gravels and part rock.

This last statement requires qualification, for, if the joining of the basins by the reversal of streams is true, then we must either suppose that the cols between these basins had been destroyed by the backward working of the stream (which would be likely to be true only in a case of approximate base-levelling), or we must suppose that the cols dividing these basins were trenched to a depth in rock equal to the rock cutting under the first hypothesis. The deep trenches of the Allegheny with their steep sides, show that the region was in the early stages of developing a new valley system, and that, therefore, the cols were presumably intact up to the heights of the old gradation-plane, at least, which, under this hypothesis, is referred to the Tertiary period. While this hypothesis escapes a large part of the rock cutting by referring it to preglacial times, it greatly magnifies the first glacial epoch. When we consider the limited area of the glaciated region between the edge of the drift and the descent to the Lake Erie valley (which limited the amount of inwash after the ice began to retire), we realize the import of this hypothesis. It means that some 300 feet of drift filled the valley for 250 miles at least, while the ice edge occupied the narrow belt between the glacial boundary and the basin of Lake Erie.

Hypothesis III.—This hypothesis postulates a limited amount of trenching of the old Tertiary gradation-plane before the ice reached the basin, the amount of this trenching being inferred from the size of buried trenches found in the bottoms of the upper Allegheny and Conewango basins, which, the theory assumes, were buried by the incoming ice without much modification and have failed to suffer any of moment since. The evidence of such trenches is rather meagre, but a small proportion of the wells in the broad valley of the Allegheny above the Kinzua col and in the Conewango and Brokenstraw valleys sink below the majority of wells to depths amounting to 75 to 100 feet. Wells not far distant from each other sometimes show this difference, from which it is inferred that the sides of the trench are abrupt. The fact that only a minor percentage, perhaps one in ten, of the wells in these basins enter this deeper portion, seems to indicate that it was only the beginning of a process of deeper erosion and had not progressed far. These trenches do not seem to be at all comparable to the trenches on the lower Allegheny below the gradation-plane. The hypothesis recognizes the fact that these northern preglacial streams could reach lower levels by shorter routes than the more southerly ones, even if the latter at length emptied into the Lake Erie basin, and that, therefore, the trenches found here are the greatest that legitimate interpretation could appeal to. Trenches in the lower section would probably be smaller.

Supposing such trenching to have taken place, the first invasion of the ice by its wash filled these lower trenches and covered the gradation-plane to the heights now indicated by the gravel sections previously given. After this, the sequence of events is the same as in the first hypothesis.

This hypothesis reduces the rock cutting, as compared with the first hypothesis, by the amount of this preglacial trench—say by the amount of 100 feet in depth and a part of the breadth of the valley. By so much as it reduces the interglacial rock cutting, it magnifies the work of the first glacial epoch because of the greater amount of filling.

We have had under consideration, in the field investigations, as one of our working hypotheses, a fourth interpretation. This was suggested partly by the phenomena themselves, and partly by the division of the old drift in southwestern Ohio and the region west into two parts, as before indicated.

Hypothesis IV.—This hypothesis presumes (1) a deposition of the high-level gravels in essentially the same way as in the first hypothesis, or possibly the third. (2) After this, there was a retreat of the ice and a period of erosion carrying the trench down to the lower rock shelves, which we have before described. (3) During the chief loess-depositing epoch, this was again filled up to heights as yet undetermined, perhaps to the base of the high level gravels, or possibly a little above, but not to the full height of these gravels, otherwise the river would not presumably have resumed a second time exactly its earlier course. (4) After the close of the loess-depositing epoch, a second stage of erosion carried away almost completely the valley deposits and cut the innermost trench down to essentially the present level. (5) Then followed the ice invasion which produced the adjacent moraines, and the late gravels, and after that, (6) the postglacial erosion, as in the preceding hypotheses.

We do not feel at liberty to make those geologists who have expressed opinions concerning the history of the region, responsible for any of these hypotheses, for they may not be formulated precisely in accord with their views.* We think however, that with minor modifications they embrace essentially all the types of hypotheses which the facts, at present known, warrant. We feel the more at liberty to leave the hypotheses to stand by themselves, without special connection with personal acceptance, since, in the limited space left us, we think it will be more profitable to discuss *their common import* than their differences and relative merits, for they all tell a common story respecting the main features of the history

* The first is the view advanced by the senior writer, in which he follows Mr. Chance in the main. Bul. 58, U. S. Geol. Survey.

of the region and the general acceptance of some one or another of them will, we feel, be very helpful in drawing interpretations of the Pleistocene history of other regions within the limits allowed by evidence.

Ratios of work done.—To better illustrate the import of these hypotheses, we may take, as a unit-measure of deposition, the amount of material poured into the Allegheny trench by the overwash and outwash from the ice while it was forming the adjacent terminal moraines and the drift connected with them, i. e. the last glacial epoch (of this region at least); and, as a unit-measure of erosion, we may take all the excavation which these moraine-headed gravels have suffered since their deposition. This last measures not only the work of postglacial time, but of all that part of the glacial period occupied in the retreat of the ice after it left the rim of the Allegheny basin, when erosion is presumed to have begun by virtue of the withdrawal of the depositing agency. For convenience we will speak of this simply as postglacial erosion.

Now, the amount of glacial filling contemporaneous with the formation of the moraines and the drift connected with them, assuming that the valley bottom was entirely free from other material, amounts to a section averaging 60 feet in depth and 2000 feet in width, as nearly as we can form a judgment from a considerable number of estimates and measurements.*

The amount of postglacial erosion, estimated liberally, may be represented by a section 30 feet deep and 2000 feet wide.*

Taking these as units, we present herewith a diagram (Figure 5) which, in the first column, shows the amount of

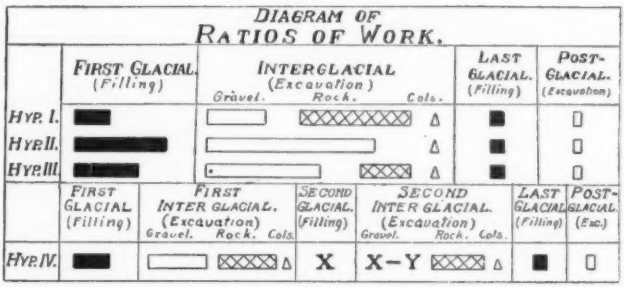


FIG. 5. Ratios of work under each of the four hypotheses of glacial filling and excavation.

filling during the first ice incursion under each of the four hypotheses. This indicates at once the ratio of the first epoch to the last in terms of valley deposition. These ratios are of

* These are based upon the Allegheny section.

course subject to obvious qualification, yet nevertheless they are very helpful toward tangible ideas. The estimates are probably not very accurate but they are representative.

In the second column, there is shown the amount of excavation that took place between the deposit of the high gravels and of the low gravels, in terms of postglacial excavation. The relative importance of these interglacial excavations is strikingly manifest. They are represented by two symbols, the one indicating excavation in drift, the other, excavation in rock. The excavation of the cols, which is probably to be regarded as somewhat nearly the same in all cases, is merely indicated as a common factor. In the third column is indicated the valley deposition of the last glacial epoch, which is the unit of deposition, and alike in all cases, and in the fourth column, the postglacial excavation, which is the unit of excavation and alike in all cases.

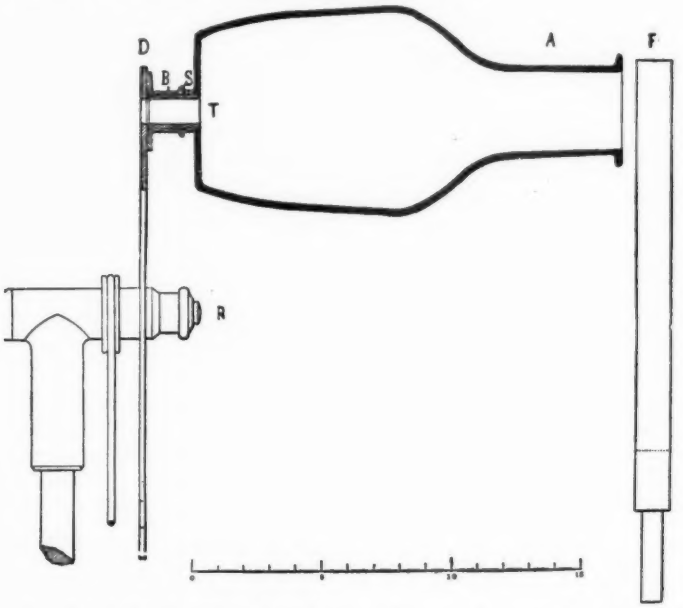
The import of all these hypotheses is alike on most of the vital points. They all greatly emphasize the importance and significance of the first glacial epoch. This is especially true of the second one. They all show very important intervening excavations when compared with the erosion that has taken place since the glacial period. This is especially true of the first and notably true of the third. They all indicate that, while the last glacial invasion was very much more pronounced in its apparent effects and in the expression it took on, it was, after all, much the smaller factor of the total accomplishment of the glacial period.

ART. XXV.—*An apparatus to show, simultaneously to several hearers, the blending of the sensations of interrupted tones;* by ALFRED M. MAYER.

IN the January number of this Journal, of the current year, I described several forms of apparatus used in my observations on the frequency of the interruptions of simple sounds required to blend these sounds and obtain from them continuous and uniform sonorous sensations. These experiments gave the data of the law connecting the pitch of a sound with the duration of its residual sensation.

The various apparatus described in that paper are, however, unsuited to exhibit the phenomena to more than one hearer at a time. To enable many hearers to observe simultaneously the phenomena I have devised the apparatus shown in the figure.

A brass tube, T, of 1·25^{cms} interior diameter and 1·8^{cms} long is cemented in a hole in the bottom of the glass flask, A; which is a common form of flask, used by chemists. When the tube, T, is closed the air in the flask resounds powerfully to the sound of an UT_3 fork, F; but when this tube is open the resonator resounds so feebly as to be just audible at the distance of several feet from the flask.



If the tube be closed and opened several times in a second we shall have short loud sounds with faint interposed sounds. The opening and closing of the tube is effected by a perforated disk, D, revolving on a rotator, R. The tube, T, is placed in the circular path of the 16 holes which perforate the disk, with the mouth of the tube quite close to surface of the disk. A short tube, B, with flanges on it, slides neatly over the tube, T, and the flange of B is pressed against the surface of the disk, D, by the helical spring, S. By this arrangement the tube, T, is fully opened when a hole in the disk coincides with the opening of the tube, T, and is entirely closed when the flange of B is between the holes in the disk and gently pressing against its surface.

On slowly rotating the disk, while the fork is kept in vibration by an electro-magnet, we have the perception of power-

ful beats which become more and more frequent as the velocity of rotation of the disk is increased till, with a certain velocity, the beats blend into a smooth continuous sound, which is that given by the fork when held near its proper resonator. This sound of UT_3 as given by the blending of its interrupted sound is, however, accompanied by another and graver sound; but the existence of this additional sound does not interfere with the neat perception of the blending of the interrupted sound of UT_3. With this apparatus the blending of interrupted sounds has been shown to the entire satisfaction of a large audience.

To enable one readily to make the apparatus the following dimensions are given. The diameter of opening of mouth of flask is $3^{cms.}$. Depth of flask $16{\cdot}25^{cms.}$. Capacity of flask, including tube, T, is $483^{cub\ cms.}$

In the figure the rotator, R, is shown driven by a cord. It is necessary, if an accurate determination is to be made of the duration of the residual sensation, to drive the disk by gearing as is done in the apparatus I have used. When the disk is driven by a cord one can show the blending of interrupted sounds, but an accurate determination of the duration of the residual sensation is prevented by the friction which exists between the flange of B and the disk, though the surfaces of these are coated with a film of oil.

ART. XXVI.—*The Post-Eocene Formations of the Coastal Plain of Alabama;* by EUGENE A. SMITH, University of Alabama.

THE succession of the Post-Eocene formations of the Coastal Plain of Alabama as brought out by the work of our Geological Survey, is in descending order, as follows:

QUATERNARY.

Recent and Pleistocene.

1. Soils, and rain wash, River alluvium, and Coast formations (Biloxi).
2. Mobile Bay formation, Second Terraces or Second Bottoms of the rivers, and the mantle of Ozark or Geneva sands.

Of undetermined Classification.

The Third, or Main River Terraces, and the Lafayette mantle of pebbles, sands, and loam. (The Lafayette is by some considered as Pre-glacial Pleistocene, by others as late Pliocene.)

TERTIARY.

Miocene.

1. The Pascagoula, upper Miocene.
2. The Grand Gulf, lower Miocene.

Eocene.

The Biloxi.—Concerning the soils, rain wash and recent river alluvium, we need say nothing here, but the character of the coast deposits now in course of formation, has not heretofore been clearly defined. Mr. L. C. Johnson has recently given this subject some study and according to him, these deposits consist of alternations of sand and fine mud or clay to the depth of many feet. The agencies which have contributed to their accumulation are the waves from the Gulf, the minor rivers of Alabama and Mississippi, and the Mississippi River itself.

The washings of sand upon the coast, and the delivering of sediment by the minor streams are constant factors, but the contributions from the Mississippi are occasional, occurring only when in times of flood the river breaks through the levees and spreads over the lowlands on each side of the main channel. Mr. Johnson has shown how this river a few years ago, pouring its waters through the Nita Crevasse into Lake Ponchartrain and Mississippi Sound, covered the Coast sands with a varying thickness of its sediments as far east as the western border of Alabama and almost to the mouth of Mobile Bay, driving out the salt water fish and completely destroying the oysters and other molluscs which were unable to retreat. At Biloxi, borings for artesian water have given a section showing alternations of sand with mud or clay down to the depth of 80 feet or more, and from this locality Mr. Johnson has proposed the name Biloxi for the formation, the lower part of which is probably of Pleistocene age. The upper part of the Biloxi may hence be considered as the marine equivalent of our river alluvium, and the sediments now accumulating in Mobile Bay will form the estuarine connecting link between the two.

Second Terraces and Geneva Sands.—As the Biloxi borings show the gradual passage of these modern coast accumulations into what must be considered as the marine equivalent of the Port Hudson of the Mississippi River, and just as these Port Hudson equivalents are seen along the lowlands bordering the coast, so in Mobile Bay, beneath the sediments now accumulating, and along the western coast, notably on Mon Louis

Island,* we find the marine or estuarine equivalents of our river terraces, in an ancient deposit with imbedded shells, not of extinct species, it is true, but of species not now inhabiting the same localities.† As we come up the bay coast towards Mobile, we find this marine or estuarine deposit giving place to a blue clay with stumps and roots, underlying several feet of sands and yellow loam, thus assuming the characters of the river terraces.

The relations of the Quaternary formations of the Gulf States were first clearly defined by Dr. Hilgard,‡ from their exposures along the Mississippi River. In descending order they are as follows: Yellow loam, Loess, and Port Hudson. The first of these, the Yellow loam, is a fine grained siliceous clay with only a moderate percentage of lime, forming the soils over a large area especially in the northwestern part of Mississippi and the adjacent parts of Tennessee, where it may be seen for at least thirty miles from the river bluff. The Loess is a fine calcareous silt which has often been described, and which in this country seems to be confined to the immediate drainage area of the Mississippi River, and to be composed of materials of Glacial origin. It is strongly calcareous, effervesces with acids, and contains in addition a large amount of carbonate of lime in the form of concretions or "puppets." The loess, unlike the yellow loam, occupies a comparatively narrow belt along the river. The Port Hudson consists of sands with occasional gravel, alternating with greenish or bluish clays, which, especially in the lower parts, hold imbedded drift wood, roots, and stumps in most perfect state of preservation. These clays are like the loess, strongly calcareous and contain similar concretions of carbonate of lime. The present channel of the Mississippi lies in general in this stratum, which, tempered by the later deposits of the river, gives rise to the fertile "buckshot" and other soils of the alluvial plain.

The corresponding deposits along the larger rivers of Alabama constitute what are commonly known as the Second Bottoms or Second Terraces.

These are flat benches, usually not more than a mile in width, and are entirely above overflow except where locally lowered by erosion, and they therefore vary in height from fifty or sixty feet above low water mark along the northern edge of the coastal plain, to not more than ten or fifteen feet in

* On Mon Louis Island at the mouth of Mobile Bay, we find below the white coast sands, a bed containing oyster shells, and below that a blue clay with stumps and other vegetable remains, thus establishing a connection between the Biloxi of the Coast and the Second Terrace formations of the upper part of the Bay and of the rivers.

† D. W. Langdon, Jr., this Journal, vol. xl, p. 237.

‡ This Journal, vol. xlvii, Jan., 1869.

the lower courses of the rivers. In all cases they are only a few feet above the level of the first bottom, or present alluvial plain. The surface material of universal occurrence along these flats is a fine yellow loam several feet in thickness, which is everywhere an excellent "brick clay," and everywhere forms the basis of soils of more than ordinary fertility. For this reason we find most of the great plantations of former days located upon this terrace. The yellow surface loam is underlaid by ten feet or more of grayish sands, into which it gradually shades: near the base of the sands it is common to find pebbles. It is not very often that a fresh clean section can be observed down to the level of low water, because of *talus*, and deposits of recent river muds, but when such sections are exposed, they show below the gray sands a varying thickness of dark gray or blue clay filled with fragments of vegetable remains in the shape of drift wood, roots and stumps, in a state of preservation ranging from what can hardly be distinguished from fresh drift wood, to highly bituminized material. It is probable that this blue clay underlies all the second bottoms of our larger streams, though it is generally hidden by recent deposits. The subjoined sections from localities embracing the entire coastal plain, appear to justify this conclusion:

(*a*) At the site of old Fort Jackson, a few miles below Wetumpka, the Coosa and Tallapoosa Rivers approach within a quarter of a mile of each other, and a "cut-off" has been formed connecting the two channels. Here is shown a perfect section of the entire second bottom formation. Near the low water mark is the blue clay stratum filled with stumps, twigs, and roots, all in a remarkable state of preservation. The blue clay is covered by at least 25 feet of gray sands capped with the usual surface loam of the Second Bottom plain. If we should be disposed to consider the blue clay stratum as a recent river swamp deposit, and *only in appearance* below the sands and loam by reason of re surfacing or overplacement, this section extending entirely across the Second Bottom terrane which makes the plain between the two rivers, would leave no room for doubt as to the relative position of the constituent members above named.

(*b*) At McIntosh Bluff, on the Alabama River, about fifty miles north of Mobile, a similar dark gray or bluish clay filled with vegetable remains, may be seen below the yellow loam and sands; and wells sunk in any part of the second bottom plain there, pass through this blue clay stratum before reaching water in the sands which underlie it, usually less than thirty feet from the surface. From this it would seem that in some places at least, the blue clay forms a layer between sands.

(*c*) Along the western shore of Mobile Bay, just below Frascati, the storms of last October washed away long stretches of the bluff, and exposed the structure of the Mobile terrace in the most perfect way. A section of this shows below the recent surface sands, a yellowish loamy sand about five feet thick; then a layer of transition material consisting of yellowish sands with lumps of gray clay one foot and a half; then a layer of lignite from six to twelve inches, and below that down to the level of low tide, and possibly still lower, six feet or more of blue clay containing many stumps and limbs, or roots, bituminized on the outside, but of the nature of yellow rotten wood inside. The same blue clay is reached in wells at many points on the Mobile terrace, at a distance from the actual coast.* This is substantially the succession of strata that may be seen along both the great rivers tributary to Mobile Bay, as well as along the Chattahoochee.

Along the smaller streams emptying into these larger rivers and into the Gulf, the yellow loam and blue clay stratum are rarely, if ever, seen, and the entire second terrace consists of the gray sands mixed with pebbles in the lower parts. In the southern parts of the State generally, and especially in the southeastern, these gray sands form not only the second terraces of the creeks, but are also spread over the divides up to altitudes of 100 feet above tide. Where this is the case the streams rarely have swamps, but the pine-clad second-bottom sandy plain reaches to the very brink of the channel. The sands usually rest unconformably upon the red loam of the Lafayette, though sometimes when this has been removed by erosion, upon the underlying Tertiary formations. Along the Chattahoochee River, and probably along some parts of the Alabama also, these sands occur as a sort of upper second terrace, outside of and a few feet above the usual yellow loam terrace. The growth on the sand terrace is almost exclusively the long leaf pine, while on the true second terrace the growth is much more varied.

We have suggested the name of Ozark or Geneva sands for these beds, which seem to correspond very closely with what have been described by Mr. McGee in other States to the north of Alabama. Here as there they occur along the streams, in the lowlands, and over the divides, corresponding to the fluvial, low level, and interfluvial phases of the Columbia formation. In the lower part of Alabama, these beds lie as if spread upon an undulating surface, and in this respect resemble the Lafayette formation to be described below. They appear to have been deposited upon a gradually emerging sea bottom, the last

* Wherever penetrated in these wells the blue clay stratum is found to be underlaid by white sands.

stage of this emergence and a pause in it being recorded in the yellow surface loam of the Second Bottom of the larger streams.

If we compare these Pleistocene deposits of Alabama with those of the Mississippi River, we shall mark the following:

1st. The Port Hudson clay of the Mississippi finds its parallel in our blue clay stratum with its plant remains. The Port Hudson clay, however, is far richer in lime, effervesces with acids, and contains concretions of lime carbonate, something not yet observed in Alabama. 2d. The sands present no material points of difference in the two states: in both occur masses of pebbles, and both are found as second terraces. 3d. The loess is not found in Alabama. 4th. The yellow loam of Mississippi finds its counterpart in the uppermost layer of our second bottom; the published analyses of these loams, given in volumes V and VI of the Tenth Census Reports, show very closely similar chemical composition. The main difference is in its distribution in the two States, the yellow loam of Mississippi being spread over an area of thirty miles or more from the river bluff, while with us the area rarely exceeds a mile. The explanation of the variations in the character of the materials and the distribution of the Pleistocene of Mississippi and Alabama, is to be found, I think, in the following considerations: (*a*) Dr. Hilgard has shown that the axis of the Mississippi River has been the region of greatest oscillation in this part of the continent during Post-Eocene time, the aggregate of depression and elevation being 1200 feet.* A depression of 450 to 500 feet would allow the waters of the great river to spread beyond its banks as far as we now find the yellow loam. Moreover, the valley of the Mississippi beyond its alluvial plain, is much wider than the corresponding valleys of the Alabama rivers, and the same amount of depression would on this account cause the flooding of very unequal areas in the two cases. (*b*) The Mississippi drains a region which was once covered by glaciers, and its sediments naturally contain much material of Glacial origin. The loess is generally, in this country at least, admitted to be of this character, and the high percentage of carbonate of lime in the clay and its lime concretions, are probably due to the same cause. Our Alabama rivers had no glaciated areas to draw upon for their materials, and they have deposited no loess, no highly calcareous clays. (*c*) In both States, the second bottoms of the minor streams are, as a rule, sandy throughout, and lack the yellow loam capping. This at least seems to be the character of the second terraces of all the rivers of Mississippi that are tributary to the great river, while Pearl and Leaf Rivers that flow into the Gulf

* Hilgard, this Journal, vol. xliii, p. 399.

directly, have the yellow loam similar to that of the Alabama rivers. Perhaps the more rapid slope of these minor streams may have prevented the deposition of anything so light and fine grained as the yellow loam.

Mr. Johnson believes that he has traced the Port Hudson clays with their included roots and stumps, continuously along the Mississippi shores eastward to the Alabama line, where they form the basis of the Pine Meadows of Mississippi and of similar flats along the waters of the Escatawpa in Alabama. But between the waters of the Escatawpa and the Bay of Mobile, intervenes a great deposit of Lafayette extending as a high ridge down to within a few miles of the Gulf. The submarine prolongation of this probably interposes a barrier to the extension of the true Port Hudson beds quite up to the entrance of Mobile Bay. We should be inclined to retain the name Port Hudson for these Pleistocene formations in Alabama, but for the manifest differences in the origin of the materials in the two States, and for the break in their continuity along the Gulf coast; but that the Alabama Second Bottom deposits, from stump layer to yellow loam capping, are the equivalents in time of the Port Hudson, Loess, Yellow loam series of the Mississippi River, can, I think, hardly admit of doubt; nor is there much room for doubt that they are in the main, equivalent to the Columbia formation of Mr. W. J. McGee.

Third Terraces and the Lafayette.—Our larger rivers have a third terrace still more extensive and important than the second. It is upon this terrace, often three or four miles wide, that so many of our river towns are situated, e. g. Tuscaloosa, Coffeeville, Jackson, Claiborne, Selma, Montgomery, Girard (opposite Columbus, Ga.), and Columbia. The third terrace is from 75 to 100 feet above the second, and exhibits in its structure two sets of materials; a substratum of Cretaceous or Tertiary, and a mantle of pebbles, sand, and loam of much later date, which lies upon a deeply eroded surface of the older formations and varies correspondingly in thickness. The average on the terraces may be placed at about 15 feet, but where old hollows have been filled up, the thickness may be as much as sixty feet, as may be seen for instance, within the limits of the city of Tuscaloosa.

The capping mantle of the third terrace is in the quality and arrangement of the material, so far as I have been able to make it out, identical with the beds which under the name of Orange Sand or Lafayette are spread more or less continuously over the entire coastal plain of Alabama, Mississippi, and Georgia and probably of other States beyond, in thickness

varying from a few feet near the inland margin of the coastal plain to more than 100 in the counties bordering the Gulf.

Thousands of observations in this and other States, show that the beds of Lafayette materials occur at elevations differing by two or three hundred feet in localities closely contiguous, precisely as if the deposits had been laid down mantlewise upon a previously eroded surface, the main topographic features of which were at the time of deposition essentially what they now are. It seems almost necessary to consider the third terraces, either as marking the very latest episode in the deposition of the Lafayette, or as a result of its rearrangement and redistribution in times very much more recent than that of the first deposition on the heights, nor do I see how its present position on such different elevations, along slopes, and in general so closely conforming with the existing land relief can be explained except as due in some measure to rearrangement, and yet after many years of close examination of these deposits, I have been unable to discover any material difference between the Lafayette on the hill tops, the Lafayette on the slopes, and in the valleys, and the Lafayette upon the river terraces, whether in the material themselves, or in their relative positions, and for this reason all its phases are considered under one head.

In Mississippi at the typical locality, there are great accumulations of cross-bedded sands of this formation, that have few if any representatives in this State, where the great bulk of the Lafayette consists of rounded water-worn pebbles of quartz, chert, and quartzite, and rounded grains of iron-stained sand mixed with some red clay, and with a few small rounded pebbles of limonite. In the Chattahoochee drainage scales of mica are also abundant. Where all three of the principal constituents above named, pebbles, sands, and loam, occur together, as a rule the upper part of the formation is a very sandy red loam, while the pebbles are mostly to be found in the lower part. Where the pebbles are absent the surface is usually red loam, with the sands below, and in some places the whole formation is sand.

The pebbles sometimes contain markings or fossils which show that they are fragments of the siliceous rocks of the Sub-Carboniferous, Silurian and Cambrian and Crystalline formations, and in their distribution they are more localized than the other main constituents. They are most abundant and of larger size in two locations: 1, along the line of contact of the formations of the coastal plain with the Paleozoic terranes, i. e. along a belt 10 or 15 miles wide stretching from the northwestern corner of the state around in a curve to Columbus in Georgia. If, at the beginning of the Lafayette period,

the whole coastal plain were submerged, and the waters of the Mississippi Gulf lapped up on the Paleozoic terrane, the pebbles, sands, etc., washed down into this Gulf would come to rest along this old coast line. 2. The other main pebble streams appear to follow the principal lines of drainage, not being confined, however, to the present narrow channels of the rivers, but occurring beyond the third terraces, on the slopes leading down toward these channels, often at a distance of 25 or 30 miles on each side, and sometimes over the divides. As if, upon the comparatively rapid emergence of the coastal plain from below sea level, the continuing currents from the land either carried new contributions of pebbles and other materials, or took up and redistributed those previously deposited along the coast line mentioned, down the wide shallow drainage valleys, and over the low divides. The third terraces may perhaps mark a pause in this upward movement occurring towards the close.

The two authors who have given this formation most study are Dr. Eugene W. Hilgard and Mr. W. J. McGee. The former refers the origin of his "Orange Sand" of the great Mississippi embayment, to a period of continental elevation, and the deposition of its materials essentially to fresh water in the form of broad shallow floods coming in from the northward and practically devoid of organic life of which the remains would be likely to be preserved.* On the other hand Mr. McGee accounts for the structure and disposition of the Lafayette materials upon the assumption of a submergence of the coastal plain below the waters of the Gulf and the invasion of the sea to the landward limit of this plain, accompanied by a warping of the land and a seaward tilting which stimulated the streams to greater activity both of erosion and transportation. The total absence from the formation of any traces of marine life finds its explanation by Mr. McGee in the comparative rapidity of the submergence and subsequent emergence of the coastal plain. Both authors assume continental elevation, or at least increased seaward slope of the areas beyond the coastal plain, while they differ in their ideas as to the position of the coastal plain during the time of accumulation of the deposits, the one requiring shallow submergence below sea level, the other assuming the flooding of this plain (above sea level) by fresh waters from the land. The wide distribution of these deposits over the whole coastal plain of the United States from the Potomac to the Rio Grande, with essentially the same characters of material and structure, favors the one view; while the peculiar structure of the deposits, the total absence of all sign of marine life, and of beach or coast mark-

* This Journal, vol. xliii, p. 394.

ings favor the other. On any theory yet offered, there are many phenomena difficult of explanation.

That the Lafayette-coated surfaces have suffered a great amount of denudation is everywhere plainly to be seen, and that the amount of this denudation increases with distance from the sea may, I think, also be shown. This would lead us to conclude that the deposition of the Lafayette extended over a long period of time, and that the landward margins of the area covered by it were being denuded while accumulation was still going on further to seaward. Thus, we find upon some of the hills of the Coal Measures in Alabama (Walker County) a good many miles northward from the main mass of the pebbles, etc., covering the junction of the Paleozoic and Cretaceous formations, occasional small remnants of the Lafayette in the form of thin beds of pebbles and sands, capping some of the highest summits, while all trace of this formation has disappeared from the adjacent valleys. Over the Cretaceous terranes there are many spots entirely bare of Lafayette, and the same is true of some of the lower members of the Eocene, but over the newer Eocene and the whole Miocene area the covering of Lafayette seems to be not only continuous, but also of greater thickness than over the older formations. Where it comes down within a mile or two of the coast, as in the divides of Mobile and Baldwin Counties, the thickness cannot be less than 100 feet and it may be more. Over the entire coastal plain the thickness cannot average more than 25 feet, if so much.

Concerning the age of the formation, we know certainly that it lies between the upper Miocene and those beds of undoubted Pleistocene age which we have described under the name of Second Terraces. If the phenomena of glaciation be taken as the criterion of the Pleistocene, then the Lafayette would have to be classed as Pre-Pleistocene, since yellow gravel beds, presumably of this age, have been traced up to and underneath the oldest of the Glacial deposits, and as yet the existence of materials of Glacial origin among the Lafayette beds seems not to be proven beyond question.

And further, the general appearance of the formation and the demonstrably great amount of erosion which it had suffered before the deposition of the undoubted Pleistocene beds, would lead us to conclude that a long period of time and important physical changes occurred between the accumulation of the Lafayette and of the Pleistocene deposits. On the other hand, the phenomena of the distribution of the Lafayette beds and their manner of accumulation, so utterly unlike those of any of the earlier Tertiary formations of the Gulf coast, make it difficult to fit the Layfayette into the Tertiary.

If the great amount of Post-Lafayette erosion should be counted a difficulty in the way of placing the Lafayette deposits in the same category with the Pleistocene, we should have the same difficulty in the equally great if not greater, amount of erosion between the Miocene and Lafayette.

While it must be admitted that the Glacial period stands by itself, sharply distinguished from anything which preceded it, and that Glacial deposits and their derivatives may be clearly distinguished from any other class of deposits, it must also be admitted that the Lafayette beds in their distribution and structure stand out as clearly distinct from anything that preceded them as do the Glacial deposits; they indicate equally great physical changes, and in many respects, especially in their relations to the underlying formations, more nearly resemble some of the Glacial deposits than they do anything else. Besides, the conditions necessary to glaciation could not have been reached instantly, there must have been physical changes that led up to it and made it possible, and it would seem to me not unreasonable to place these precedent deposits along with those due to the Glaciers themselves in the Quaternary.

Pascagoula and Grand Gulf.—Dr. Hilgard, in his Geology and Agriculture of Mississippi, gave the name Grand Gulf, to a great series of sandstones, mudstones, and clays, which in that state overlies the Vicksburg Eocene. These beds were practically destitute of organic remains except some obscure impressions of plants, and perhaps a shell or two, for which reason it has been impossible to fix the age of the formation more definitely than as post-Eocene Tertiary, and probably as Miocene. In 1889 Mr. L. C. Johnson, while examining the Grand Gulf of Mississippi, discovered near Vernal in Greene County, on or near the Pascagoula River, certain beds with marine or estuarine fossils which he at the time considered a part (the upper member) of the Grand Gulf, but so different as to deserve another name. He accordingly suggested the name *Pascagoula.*

In November, 1887, Mr. D. W. Langdon, Jr., under the auspices of the Alabama Geological Survey, made an examination of the banks of the Chattahoochee River from Columbus, Ga., to the Gulf, and discovered nine miles above River Junction (Chattahoochee), overlying the Vicksburg limestone and extending down the river as far as Alum Bluff, a series of marine Miocene beds, consisting of many feet of somewhat siliceous and argillaceous limestones overlaid by highly fossiliferous sands. The excellent state of preservation of the contained shells, renders easy and certain the identification of the geological age of these beds, which is Miocene, the limestone beds and the lowest of the fossil-bearing strata at Alum Bluff

being lower Miocene (Chattahoochee and Chipola divisions), while the uppermost of the fossil beds at the bluff are considered as upper Miocene (Chesapeake). These discoveries soon attracted the attention of geologists and collectors, and other localities were speedily found where the lower shell bed of Alum Bluff was more easy of access and more prolific of well preserved specimens than at the Bluff itself. Such localities on Chipola River have furnished the name which is now commonly applied to these beds. Between these fossiliferous sands, which according to Mr. Dall, contain a certain number of Eocene shells, and the undoubted Vicksburg orbitoidal limestone, lie as above intimated, some two to three hundred feet of calcareous rocks, constituting the series to which Mr. Langdon has given the name Chattahoochee. Thus the existence of marine basal Miocene beds was established along or very near to the eastern border of Alabama.

Then in 1892, Mr. L. C. Johnson, working for our Alabama survey, discovered at Healing Springs in Washington County, immediately contiguous to the Vicksburg limestone, the characteristic gray siliceous mudstones splotched with purplish ferruginous stains, of the Grand Gulf formation.

These and other equally characteristic Grand Gulf rocks, dark gray clays, he followed eastward through the lower part of Monroe County and through Escambia to the Conecuh River, on the borders of which they are well exposed in the vicinity of Mason, always immediately adjacent on the south to the Vicksburg limestone. At Roberts on Silas Creek, a tributary of the Conecuh River, Mr. Johnson observed these characteristic and unmistakable Grand Gulf beds, underlying and in direct contact with sands containing shells which Mr. Dall has identified as belonging to the Chipola division of the Chattahoochee River series. And a few miles further south in Florida at Oak Grove, Mr. Johnson found a shell bed with excellently preserved forms which Mr. Dall identifies as of Chesapeake or upper Miocene age. The Pascagoula shells above alluded to, have also been classed with the Chesapeake, and borings from an artesian well at Mobile, have furnished a number of shells characteristic of the same period. We have thus certain evidence from our Alabama work, that the Grand Gulf occupies a place between the Vicksburg limestone and the Chipola division of the lower Miocene, being thus identical in position with the calcareous beds of Langdon's Chattahoochee section. Although the Grand Gulf rocks have not been followed farther eastward than the vicinity of the Conecuh River, being deeply covered by sands, it seems to us reasonably certain that the siliceous and argillaceous rocks that characterize this formation in the west, become calcareous eastward, and find their marine equivalents in the Chattahoochee of Landgon.

ART. XXVII.—*Variscite from Utah;* by R. L. PACKARD.

IN December, 1893, a specimen of a beautiful green mineral was sent to Mr. Merrill, Curator of Geology in the U. S. National Museum, for identification by Mr. F. T. Millis of Lehi, Utah, who stated that it occurred in the form of "nuggets" in a quartz vein near Lewiston, Utah, some twenty miles west of Lehi. Upon a cursory examination the mineral was found to have the blowpipe characteristics of peganite, as given by Dana, but as this species has not heretofore been reported from the United States Mr. Merrill asked me to make an analysis of it. The result showed that the composition is the same as that of variscite, and is as follows:—

H_2O	22·95
P_2O_5	44·40
Al_2O_3 (by difference)	32·65

The other analyses of variscite are given by Dana as follows:—

	Voightland.	Arkansas.
H_2O	22·85	23·80
P_2O_5	44·05	44·35
Al_2O_3	31·25	31·85

while the callainite described by Damour gave

H_2O	23·67
P_2O_5	42·58
Al_2O_3	29·57

The mineral is compact or crypto-crystalline, and dull, not resembling the usual form of variscite in these respects. It flies to pieces before the blowpipe and turns a fine purple or lavender color. This is a characteristic of peganite but Chester remarked it in the case of variscite from Arkansas.* With cobalt it gives a blue color. The flame is tinged green by the phosphoric acid. It is insoluble in acids before heating, but afterwards dissolves readily in hot acids and alkalies. The solution in acid gives no color when a platinum wire is dipped in it and then held in the Bunsen flame. This solution gives no reaction when H_2S gas is allowed to pass through it for half an hour or more and the precipitate with ammonia and sulphide of ammonium is perfectly white. No manganese or chromium was detected by fusing portions of this precipitate with sodium carbonate and with soda *plus* chlorate of potassium respectively. In the large specimen sent to the Museum, the green mineral occurs in nodules separated from each other by

* This Journal, vol. xiii, 1877, p. 295.

banded envelopes of a yellow mineral between which and the green is a powdery white coating, the whole forming a large nodular mass nearly seven inches in its longest diameter. A partial analysis of the yellow mineral and the white powder which separates it from the green, gave for the yellow,

H_2O	16·89
P_2O_5	34·43

and for the white powder

H_2O	19·74
P_2O_5	37·43

showing a progression from yellow through white to the green. Both the white and yellow substances leave an insoluble residue which is larger in the yellow, and as the relation between the water and acid is about the same in all three cases it seemed probable that the three are practically the same mineral, the green being pure, the other two carrying an impurity. A thin section of the green mineral viewed by polarized light shows it to have a finely granular structure with an occasional spherulitic area. The grains do not present well defined crystallographic features but are irregular in outline, and of different sizes.

The banded mineral also shows a granular structure but the section is traversed by streaks of an opaque yellowish substance to which the prevailing yellow color of the bands is doubtless due. The specific gravity of the green mineral is 2·62 and its hardness about 4.

No information was furnished which would throw light on the question of the source or genesis of this mineral, of which the present appears to be the second publicly known occurrence in this country.

Washington, D. C., Jan. 25, 1894.

ART. XXVIII.—*The Appendages of the Pygidium of Triarthrus;* by CHARLES E. BEECHER. (With Plate VII.)

SINCE the previous publications in this Journal, on the antennæ and thoracic legs of *Triarthrus Becki*,* additional features have been worked out from the material in the Yale Museum, and it is now proposed to give the main characters of the appendages attached to the pygidium, or caudal shield. The structure of the under side of the head will next be de-

* Antennæ and other Appendages of Triarthrus Beckii; by W. D. Matthew. This Journal, August, 1893. On the Thoracic Legs of Triarthrus; by C. E. Beecher. This Journal, December, 1893.

scribed, after which it will be possible to review the present knowledge of *Triarthrus*, together with its bearings on the position and affinities of the Trilobita.

Walcott first determined the presence of pygidial legs, and in a restoration of the ventral surface of *Calymene senaria*, one pair is represented to each annulation of the axis.* Matthew (l. c.) figured and described an imperfect and poorly preserved specimen of *Triarthrus*, which obscurely showed two flaps or fin like extensions, beyond the lower edge of the pygidium. These he considered as possibly anchylosed pygidial limbs.

The specimens here described leave little to be desired in the way of perfect preservation. The lower side of a number of individuals has been exposed, showing the ventral membrane with the appendages attached. The dorsal shield has also been removed from other specimens, and the appendages exposed from that side, so that a very complete idea may be had of the character of the limbs, with many of the finer details of structure. The small size of the pygidium of *Triarthrus*, and the great number of elements in the appendages, however, render it difficult to remove the shaly matrix completely. Moreover, the overlapping and crowded arrangement of the limbs make the structure of the pygidial region seem quite complicated.

In *Calymene*, as worked out by Walcott, these appendages, of which the endopodites alone are shown, are weak and slender, and appear to show important differences from those of *Triarthrus*.

In *Triarthrus*, the thoracic legs near the head are composed of comparatively long joints, the proximal ones only of both endopodite and exopodite being somewhat flattened and expanded (figure 1). The functions of these two branches are clearly indicated, the endopodite being adapted for crawling and the exopodite for swimming. From the anterior region of the thorax, there is a gradual and progressive change in both branches of the legs increasing their functional powers as swimming organs. When the pygidium is reached, the endopodites preserve their slender, jointed distal portion, but the proximal part

1.

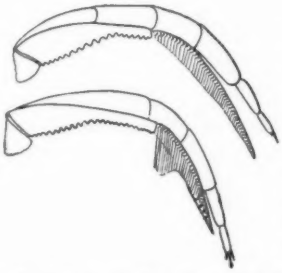


FIGURE 1. — *Triarthrus Becki* Green; dorsal view of right legs of second and third free thoracic segments. × 12.

*The Trilobite: new and old evidence relating to its organization. Bulletin of the Museum of Comparative Zoology, vol. viii, No. 10, 1881.

is composed of segments which are considerably expanded transversely, thus making a paddle-like organ, the anterior edge of which is straight, while the posterior one is serrated by the projecting points of the expanded segments. These points bear small bundles of setæ (Plate VII, figure 2).

The extreme posterior endopodites are made up of endites having a width two or three times greater than the length. A young individual (Plate VII, figure 3) presents pygidial endopodites, having this character while the lower thoracic segments (not represented in the figure) bear endopodites similar in form to a^{VI}, in figure 2. As these phyllopodiform appendages are the youngest and most immature on an adult *Triarthrus*, and are the prevailing form on the pygidium of an adolescent specimen, they probably indicate some primitive feature or simple type of trilobite leg. Their resemblance to the endopodites of *Apus*, figure 4, or to a typical phyllopod limb is very marked.

There is little apparent change in the structure of the exopodites from the anterior thoracic segments to the pygidium, as throughout this length they retain the large basal joint with a slender many jointed end carrying a long fringe of closely arranged setæ. As shown in figure 1, these fimbriæ overlap, and project behind the pygidium, forming with the endopodites a fin-like expansion on each side, especially well adapted to propel and guide the animal in swimming. They may have served also as egg carriers. As far as known, there was but a single pair of biramous limbs to each annulation, or potential segment, of the pygidium.

Yale Museum, New Haven, Conn., March 9th, 1894.

EXPLANATION OF PLATE.

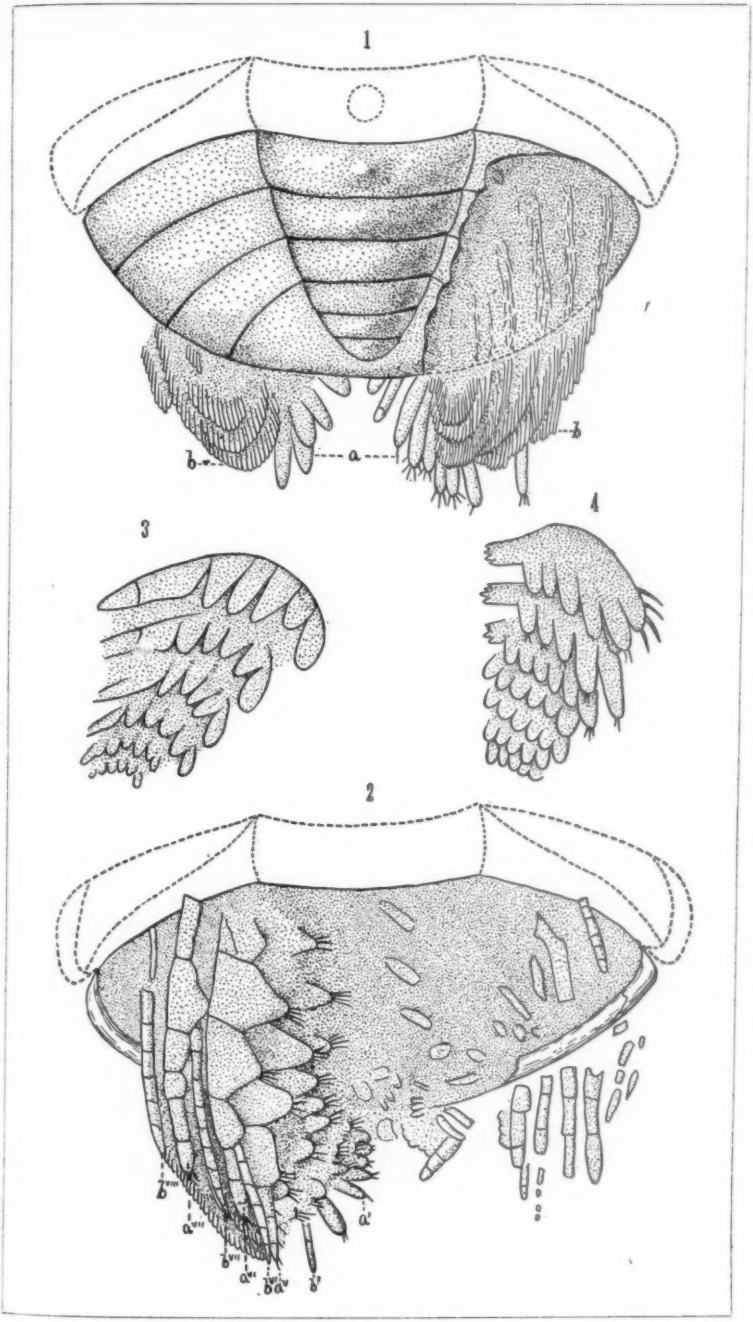
Triarthrus Becki Green.

FIGURE 1.—Dorsal side of pygidium, showing fringes of exopodites (*b*) and ends of endopodites (*a*). The last free thoracic segment is represented in outline. Taken from an entire individual. × 16.

FIGURE 2.—Ventral view of pygidium with appendages well preserved on one side, showing expanded setiferous endites of endopodial limbs (a^{I}, a^{V}, etc) and exopodites (*b*). The last free thoracic segment is represented in outline. Taken from an entire individual. × 16.

FIGURE 3.—The endopodites (somewhat displaced) from right side of pygidium of small specimen. The two end segments of upper limb are restored. The lower limbs are minute and rudimentary. × 60. Utica Slate. Near Rome, N. Y.

FIGURE 4.—Endopodites from right side of fourth larval stage of *Apus*, enlarged. (After Claus)


1
b
a
b
3
4
2
b'''
a'''
b''
a''
ba'
b'
a'

ART. XXIX.—*On the Geological Position of the Eocene Deposits of Maryland and Virginia;* by GILBERT D. HARRIS.

IN the spring of 1830,* T. A. Conrad made a visit to the western shore of Maryland for the purpose of collecting fossil remains and observing the geological features of the region. He discovered in the vicinity of Ft. Washington beds that he correlated with the London Clay of England since they contained among other extinct species *Venericardia planicosta* of Lamarck. A few years later† he called attention to the resemblance of *Cucullæa gigantea* of this locality to a European species, and noted the similarity of *Ostrea compressirostra* and the European *Ostrea bellovacina*. In the same work he described many new species from Claiborne, Alabama, mentioned others from Vance's Ferry, South Carolina, and classified Maryland, Alabama, and South Carolina deposits alike as "Middle Tertiary or London Clay and Calcaire Grossier."

The Rogers in 1839‡ differentiated this series from the overlying Miocene and underlying Cretaceous in Virginia and correctly referred it to an Eocene horizon and described several of its characteristic species.

Conrad, in the Proceedings of the National Institution, 1841,§ mentioned many Eocene localities in the Gulf and Atlantic slope States and pointed out the resemblance of the Upper Marlboro rocks of Maryland to those of Bangor, England, *Ostrea bellovacina* he affirmed was found at either locality.

Up to this time, no stress had been laid on the stratigraphic position of the various Eocene outcrops in America; to know that they were Eocene was all sufficing. In 1855, however, Conrad‖ established three subdivisions in the Alabama and Mississippi deposits of this series, naming them in descending order, the Vicksburg, Jackson and Claiborne groups. In 1865 he instituted another, the Lignite Formation,¶ wherein he seemingly desired to include beds lying between the "Buhrstone," as described by Tuomey, and the Cretaceous. To this formation he referred the dark colored friable clays of Piscataway Creek and the basal bed of Tuomey's section on Bashia Creek, Clark Co., Alabama; but the "Marlboro rock" to use

* Jour. Ac. Nat. Sci. Phila., 1st Series, vol. vi, 1830, pp. 205 et seq.
† Fossil Shells Tert. Form. N. A., Harris' Reprint, p. [21].
‡ Trans. Am. Phil. Soc., N. Ser., vol. v, 1839, p. 347 et seq.
§ Second Bull, pp. 172–179.
‖ Proc. Acad. Nat. Sci. Philad., vol. vii, p. 257.
¶ Proc. Acad. Nat. Sci. Philad, vol. xvii, 1865.

his own expression, belongs to a higher or "Buhrstone" horizon.

Practically the same conclusions were reiterated by Heilprin* in a "Note on the Approximate Position of the Eocene Deposits of Maryland," published in the Proceedings of the Academy of Natural Sciences of Philadelphia, 1881. Conrad's stratigraphic nomenclature he modernized to some extent and used the term "Eo-lignitic" in place of Conrad's "Lignite Formation."

It was not until 1886 that the typical section of American marine Eocene, namely, that of Alabama was published. This was given in Bulletin No. 43 of the U. S. Geological Survey by Smith and Johnson. In the same year also, appeard Bulletin No. 1 of the State survey of Alabama in which Aldrich listed the known species from the various stages and sub-stages of the series. Herein is found the clue to the special problem in question, i. e., what horizon in the Alabama section does the Eocene of Maryland and Virginia (Pamunkey formation of Darton) represent. Whereas the Buhrstone and the section on Bashia Creek furnish few or no characteristic Maryland and Virginia Eocene species as neither Conrad nor Heilprin were able to show although for some cause they believed all should be relegated to practically the same horizon, the Bell's Landing sub-stage including the Bell's Landing, Gregg's Landing, and Nanafalia deposits do furnish such characteristic fossils. During a recent visit to these localities I observed that the material in which the fossils are imbedded is very similar to that of the Virginia Eocene, while the fossiliferous zones are widely separated by beds of fine dark lignitic clay. The species obtained that are most telling as indices of horizon are as follows:

Dosiniopsis lenticularis Rogers; found at Bell's Landing; also very abundant in the Maryland and Virginia (Pamunkey) Eocene. A slight varietal form from the vicinity of Piscataway Creek and Ft. Washington has been named *D. meeki* by Conrad.

Cucullæa transversa Rogers; common in the Gregg's Landing bed and in Virginia, probably simply a small variety of *C. onochela* Rogers and *C. gigantea* Conrad.

Venericardia planicosta, var. *regia* Con.; common in all members of the Bell's Landing sub-stage as well as in Virginia and Maryland.

Ostrea compressirostra Say; abundant in the Bell's Landing horizon of Alabama and in Maryland and Virginia.

Turritella mortoni, var., *postmortoni*, nov var.; very abundant at Gregg's and Bell's Landing; rare among other *T. mor-*

* Pp. 444–447.

toni from Aquia Creek, Virginia; characterized by its rather smaller size, plainer surface, extremely sharp basal carina. See figs. 1, 2, and 3.

Turritella humerosa Conrad; abundant in several varietal forms in the Bell's Landing sub-stage; common in Maryland and Virginia. This species ranges from the Midway to the Claiborne inclusive, but seems exceptionally well developed at this horizon.

Turritella præcincta Conrad; very common in the Bell's Landing sub-stage of Ala.; rare at Aquia Creek, Va. The Virginia specimens are less strongly carinated than their Alabama representatives.

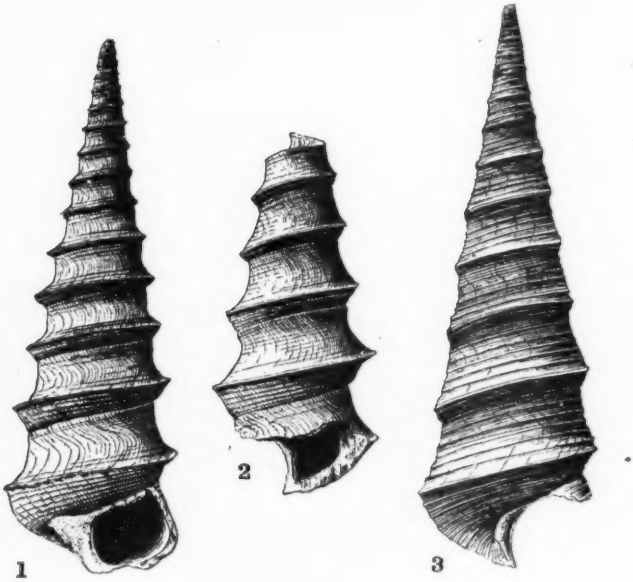
Natica, species probably new, from Bell's Landing and Maryland.

Besides these, other species can be mentioned that are found in common in the Pamunkey and the Alabama Lignitic. Here may be included *Volutilithes petrosa*, var. *tuomeyi*, *Levifusus trabeatus* var., and perhaps *Cytherea ovata* Rogers, which is likely to prove the same as *C. nuttalliopsis* of Heilprin.

The fauna of the Bell's Landing sub-stage is much more varied, i. e., contains a far greater number of species than does that of the Eocene of Maryland and Virginia. As a rule, such species as survive in the later stages of this series are here represented by unusually large varieties. While those that are common to this and the Maryland and Virginia deposits are dwarfed or comparatively smaller than their northern representatives. This however, does not invariably hold true.

As far as is yet known the different horizons of the Maryland and Virginia section contain practically the same fauna, although at some localities and horizons a few forms may appear extremely abundant, while elsewhere, they may be very scarce. It is too early however to speak with much certainty on this point. The fossils, as a rule, are poorly preserved and thus far only the commoner forms have been collected and described. There are traces of many less conspicuous ones that may serve to throw additional light on this subject when their characteristics have been ascertained.

Below will be found a general section of the Eocene series of the Southern States. It is based to a considerable extent on that given by Smith and Johnson (*loc. cit.*) though modified to include and harmonize with the writer's more recent observations. The horizon of the Maryland and Virginia Eocene is moreover, indicated.



EXPLANATION OF FIGURES.

FIGURE 1. *Turritella mortoni* var. *postmortoni* Harris, from Bell's Landing, Ala.
" 2. The same; Aquia Creek, Va.
" 3. *Turritella mortoni* Con., typical, from Glymont, Va.

	Stages.	Substages.		
Series Eocene.	Vicksburg.	Coral Limestone.		
		Vicksburg Beds.		
		Red Bluff Beds.		
	Jackson.	Moody's Branch Beds.		
		Marks' Mills Red Beds.		
	Claiborne.	White Bluff Marls (Ark.)		
		Claiborne Sand.		
	Lower Claiborne.	Ostrea sellæformis Beds.		
		Lisbon Beds.		
		Buhrstone.		
	Lignitic.	Hatchetigbee Beds.		
		Wood's Bluff Beds.	Substage.	Eocene of Maryland and Virginia.
		Bell's Landing. Bell's L'd'g Bed.		
		Bell's Landing. Gregg's L'd'g Bed.	Pamunkey.	
		Bell's Landing. Nanafalia Beds.		
	Midway.	Matthew's Landing Marl.		
		Black Bluff Clays.		
		Midway Clay and Limestone.		

ART. XXX.—*Contributions to the Crystallization of Willemite;* by S. L. PENFIELD.

As far as known willemite is a mineral of rare occurrence. The manganese variety, troostite, is found at Franklin, Sussex Co., New Jersey, in sufficient quantity to make it a valuable ore of zinc. It also occurs sparingly at the Merritt mine, Socorro Co., New Mexico, an analysis and description of it having been given by Prof. F. A. Genth * In the summer of 1891, while collecting for the U. S. Geological Survey, the writer found a well crystallized specimen on the dump of the Sedalia Copper Mine, near Salida, Chaffee Co., Colorado and, as far as known, these three are the only localities for the mineral in the United States.

Our knowledge of the crystallization of willemite is limited to a description by A. Levy† of the simple crystals from Moresnet near Altenberg and to measurements with the contact goniometer of the large troostite crystals from New Jersey by E. S. Dana‡ and Des Cloizeaux.§ From the similarity of the rhombohedral angles of willemite, Zn_2SiO_4 and phenacite Be_2SiO_4 it has been assumed by Groth‖ that willemite probably crystallizes like the latter in the rhombohedral-tetartohedral division of the hexagonal system, but no crystals have ever been described which were sufficiently modified to show the tetartohedrism.

Willemite from the Merritt Mine, New Mexico.

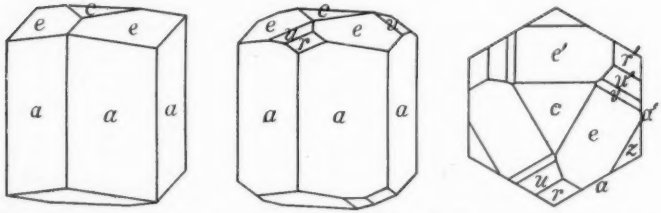
Through the kindness of Mr. Geo. W. Fiss of Philadelphia, Pa., the author has been supplied with a suite of specimens containing crystals suitable for measurement on the reflecting goniometer. The crystals are colorless, transparent and measure on the average about $0{\cdot}5^{mm}$ in greatest diameter. Some exhibit a dark center with transparent exterior, or with simply the extremities of the prism clear. The crystals occur as aggregations or as druses lining cavities in the rock. The forms which have been identified are:

c, 0001, O	*e*, $01\bar{1}2$, $-\frac{1}{2}$		
a, $11\bar{2}0$, i–2	*u*, $2\bar{1}\bar{1}3$, $\frac{4}{3}$–2l	or	$\frac{\frac{4}{3}P2}{4}\frac{l}{r}$
r, $10\bar{1}1$, 1	*v*, $\bar{1}3\bar{2}5$, $-\frac{1}{5}{}^{3}r$	or	$-\frac{\frac{3}{5}P\frac{3}{2}}{4}\frac{r}{l}$
z, $01\bar{1}1$, –1			

* Proc. Am. Phil. Soc., xxiv, p. 43, 1887. † Ann. Mines, iv, p. 513, 1843.
‡ System of Min., Sixth Edition, p. 460.
§ Manuel de Minéralogie 1862, p. 43.
‖ Tabellarische Uebersicht der Mineralien, 1889, p. 111.

Figures 1 and 2 represent the ordinary developments of the faces. The rhombohedron of the second order, u was ob-

1. 2. 3.



served intersecting both extremities of the vertical axis and always in the position required by rhombohedral tetartohedrism. The rhombohedrons z and v are of rare occurrence. All of the forms which have been observed are represented in the basal projection, fig. 3. Among a suite of specimens from this locality in the cabinet of the late Prof. F. A. Genth, sent to the writer by Dr. F. A. Genth, Jr., only the simple combination of prism and basal plane was observed.

The crystals are brilliant and give good reflections, but the faces are commonly vicinal, which renders the measurements somewhat uncertain. There was a decided tendency for the basal plane to develop into a flat vicinal rhombohedron, while the prism seemed always to be slightly warped or twisted. Although the measurements of similar angles show a considerable variation, the best of them, judging from the character of the signals, agree closely with the values calculated from the fundamental measurement of Lévy, $p \wedge p$, $30\bar{3}4 \wedge 03\bar{3}4 = 51° 30'$. It was decided, therefore, to retain his axial ratios, $a : c = 1 : 0{\cdot}6696$.

The following is a list of some of the calculated and measured angles.

		Calculated.	Average measurement.	Number of times measured.	Limits.
$c \wedge e$,	$0001 \wedge 01\bar{1}2$	$= 21° 8'$	$21° 6'$	11	$20° 40'$–$21° 28'$
$e \wedge e'$,	$01\bar{1}2 \wedge \bar{1}012$	$= 36 23$	$35 48$	11	$35 5$–$36 24$
$a \wedge e$,	$11\bar{2}0 \wedge 01\bar{1}2$	$= 71 48$	$71 39$	7	$71 14$–$71 57$
$r \wedge e$,	$10\bar{1}1 \wedge 01\bar{1}2$	$= 31 59$	$32 2$	7	$31 36$–$32 38$
$r \wedge e'$,	$10\bar{1}1 \wedge \bar{1}012$	$= 58 51$	$58 45$	2	$58 25$–$59 5$
$c \wedge r$,	$0001 \wedge 10\bar{1}1$	$= 37 42\frac{1}{2}$	$37 56$	1	
$c \wedge z$,	$0001 \wedge 01\bar{1}1$	$= 37 42\frac{1}{2}$	$37 57$	1	
$e \wedge u'$,	$01\bar{1}2 \wedge \bar{1}2\bar{1}3$	$= 11 45\frac{1}{2}$	$11 25$	3	$11 21$–$11 27$
$e \wedge u$,	$01\bar{1}2 \wedge 2\bar{1}\bar{1}3$	$= 31 36$	$31 51$	1	
$c \wedge u$,	$0001 \wedge 2\bar{1}\bar{1}3$	$= 24 3$	$23 24$	1	
$u \wedge u'$,	$2\bar{1}\bar{1}3 \wedge \bar{1}2\bar{1}3$	$= 41 20$	$40 49$	1	
$e \wedge v$,	$01\bar{1}2 \wedge \bar{1}3\bar{2}5$	$= 7 7$	$7 23$	1	

Willemite from the Sedalia Mine, Salida, Colorado.

At this locality it was observed in transparent, colorless crystals up to 3mm in diameter, having the habit shown in fig. 4. The mineral was identified by its blowpipe reactions and the following measurements:

	Measured.	Calculated.
$e \wedge e$, $1\bar{1}02 \wedge 01\bar{1}2 =$	35° 35′	36° 23′
$a \wedge e$, $\bar{1}2\bar{1}0 \wedge 01\bar{1}2 =$	71 42	71 48

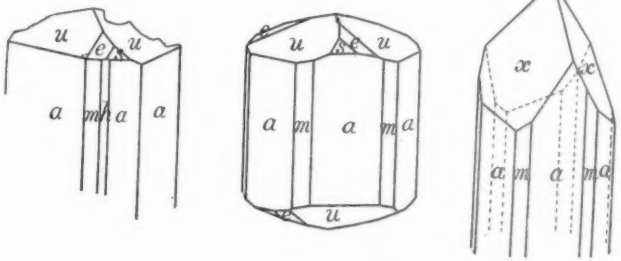
The crystal faces are warped and striated and on some of them low, vicinal prominences are developed, which are unsymmetrical with reference to the rhombohedron *e* and indicate clearly that the crystals are tetartohedral. When mounted in Canada balsam these rather flat crystals show with convergent polarized light a normal uniaxial interference figure, and a strong positive double refraction.

4.

Willemite or Troostite from Franklin, N. J.

The crystals from this locality, which are commonly found imbedded in calcite, are usually rather coarse and show simple combinations of *a*, $11\bar{2}0$; *r*, $10\bar{1}1$; *e*, $01\bar{1}2$ and *c*, 0001. In the private collection of Mr. Frederick A. Canfield of Dover, N. J., there are, however, two specimens which are worthy of special description, as the crystals exhibit combinations which are very unusual for the Franklin mines and are also beautiful illustrations of rhombohedral-tetartohedrism. These specimens were kindly loaned to the writer, who takes this opportunity of expressing his thanks to Mr. Canfield.

5. 6. 7.



On one specimen there were several nearly transparent, green prisms, attached to a gangue of massive willemite and franklinite. One of these, about 30mm long by 20mm in diam-

eter, was so attached that only a part of its faces were developed, which are represented in about their natural proportion in fig. 5. The prominent rhombohedron u is of the second order, and if it corresponds in position to u in the New Mexico willemite, $2\bar{1}\bar{1}3$, $\frac{2}{5}$–$2l$, then the terminal faces are those of the lower, instead of the upper end of the crystal,* and if symmetrically developed would appear as in fig. 6. The rhombohedron s is $11\bar{2}3$, $\frac{2}{3}$–$2r$ and e is $01\bar{1}2$, $-\frac{1}{2}$. The prisms are of the first order m, of the second order a and of the third order h, $3\bar{1}\bar{2}0$, i-$\frac{3}{2}l$, although the symbol of the latter is uncertain, as satisfactory measurements could not be made.

The second specimen contained long prisms of nearly transparent, pale-green willemite, imbedded in a pink manganiferous calcite. Only one of these, measuring about 6^{mm} in diameter, was well terminated, fig. 7. The rhombohedron x is of the third order and has the symbol $3\bar{1}\bar{2}1$, 1^3l or $\frac{3P\frac{3}{2}}{4}$ $\frac{l}{r}$. The prismatic faces are bright but the rhombohedron is dull so that measurements were made only with a contact goniometer, as follows:

	$a \wedge x$, $2\bar{1}\bar{1}0 \wedge 3\bar{1}\bar{2}1$	$a \wedge x$, $11\bar{2}0 \wedge 3\bar{1}\bar{2}1$	$x \wedge x$, $3\bar{1}\bar{2}1 \wedge \bar{2}3\bar{1}1$
Measured	28½°	54½°	102°
Calculated ..	28 5′	53 59′	102 10′

This interesting and very unusual combination of prisms terminated only by a rhombohedron of the third order is similar to that exhibited by some of the phenacite crystals from Mt. Antero, Colorado.†

On the cleavage of Willemite.

Statements are made by various authors that willemite has a distinct basal cleavage, while the manganese variety, troostite, cleaves parallel to a prism of the second order, and this variation, together with the differences in crystalline habit and chemical composition have been cited as grounds for regarding the two minerals as distinct species.

During the course of this investigation the subject of cleavage has been carefully considered. On the crystals from Moresnet either a basal or a prismatic cleavage may be produced by placing a knife blade in appropriate positions on the crystals and pressing until they break. The cleavages are poor, they can scarcely be called distinct and both are about equally perfect, although, owing to the prismatic shape, the basal is

* Owing to the rhombohedral-tetartohedrism the upper and lower ends of a crystal can not be interchanged without changing the symbols of the faces.

† This Journal, III, xxxvi, p. 320, 1888.

perhaps more easily produced. It was moreover observed that milky, white crystals yielded the basal cleavage more readily than clear, transparent ones. If the crystals are broken without care they usually show only an irregular to conchoidal fracture. The same holds true for the transparent crystals from Franklin, while the ordinary massive specimens usually present only irregular fractures. A good prismatic cleavage, which may occasionally be observed, is perhaps of secondary origin, resulting from pressure. All attempts to produce cleavages on the crystals from Salida and the Merritt mine failed, owing to their shape and small size.

In conclusion, therefore, the author believes that there are no essential differences in cleavage or crystallization between willemite and troostite which warrants their separation into distinct species.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, November, 1893.

ART. XXXI.—*On the Occurrence of Olenellus in the Green Pond Mountain Series of Northern New Jersey, with a Note on the Conglomerates;* by CHARLES D. WALCOTT.

IN company with Dr. John C. Smock, State Geologist of New Jersey, I visited, in October, 1893, several localities of the Green Pond Mountain rocks in northern New Jersey, and also crossed into Orange County, New York, to see the section of the southwestern portion of Skunnemunk Mountain.

The first locality that we examined was at a point four miles northeast of Newfoundland and two miles north of Lake Macopin, where the succession from below upward is, gneiss, bedded quartzite, massive-bedded siliceous limestone, and a belt of shales that pass beneath the conglomerate of Kanouse Mountain. The latter formation extends to the southwest and merges into the Copperas Mountain conglomerate. Fragments of Olenellus were found in the limestone. Subsequently I visited the Gould quarry, one mile north of Macopin Lake, where the section is essentially the same, but more complete.* The quartzites are separated by a slight interval of soil from the gneiss, and pass above into a conglomerate formed of white quartz pebbles in a reddish matrix. Reddish-purple sandstones also occur associated with the conglomerate, the whole forming a mass not over ten feet in thickness. The superjacent limestone has been extensively cut into in quarry-

* Geol. Surv. New Jersey, Ann. Rept. 1884, p. 52.

ing operations and dips beneath a conglomerate formed of white quartz pebbles, essentially the same as those in the conglomerate beneath the limestone. As in the section one mile to the north, an interval of slate occurs between the low ridge formed by the limestone and associated rocks and the massive conglomerate of Kanouse Mountain on the west. The discovery of the Olenellus fauna in the limestone is a positive addition to the data for working out the stratigraphy of the Green Pond Mountain area. Occurring, as it does, in a limestone that merges above and below into beds of conglomerate that are essentially of the Green Pond Mountain type, it proves that the conditions under which this characteristic formation was formed began in *lower* Cambrian time.

In a recent paper Mr. A. F. Foerste* states that "Since the rocks all dip west the conglomerates forming the eastern side of Copperas and Kanouse Mountains must be Oneida, the red sandstone above the same, the Medina, the underlying limestone, the Magnesian limestone, and the basal sandstone, the Cambrian; but instead of the term Potsdam it is necessary now until further developments, to call it Olenellus Cambrian. It is a quartzite sandstone from ten to fifteen feet thick, and so far has not furnished fossils."

The danger of correlation by lithological characteristics is shown by the reference of the limestone in which I found Olenellus to the Magnesian limestone of the Pennsylvania and New York sections. The use of the term "Olenellus Cambrian" for the sandstone or quartzite is objectionable. In the absence of fossils the correlation of the basal sandstone of one basin of sedimentation with the basal sandstone of another basin of sedimentation must necessarily be more or less conjectural.

In the report of 1868 Dr. Geo. H. Cook, the then state geologist, referred the conglomerates of Copperas and Kanouse Mountains to the Potsdam epoch of the New York series on account of their being at the base of the Paleozoic series. Mr. Foerste is now confident that they are of the age of the Oneida conglomerate of the New York section. From the data at present available it may be that the latter is correct; but, from the fact that the sediments of the Green Pond Mountain area were deposited in a basin distinct from that to the west and north, it is evident that any attempt to make exact correlations between the rock series of this basin and that of the more extensive basin of New York, western New Jersey, and Pennsylvania will be more or less theoretical. The sedimentation of the Green Pond Mountain area of New

* This Journal, vol. xlvi, 1893, p. 441.

Jersey and southeastern New York is peculiar to itself; and the use of the term "Oneida conglomerate" for the conglomerate of Kanouse and Copperas Mountains is confusing to one acquainted with the stratigraphy, and much more so to the student who endeavors to class two such unlike formations as one and the same formation. If it is desirable to correlate the conglomerate of Kanouse, Copperas and Green Pond Mountains with the Oneida conglomerate of the New York series, I think less confusion would be caused by calling it the Green Pond conglomerate, and stating that this conglomerate is correlated with the Oneida conglomerate under the belief that it occupies the same stratigraphical position. When I speak of the Green Pond conglomerate, it is understood that the conglomerates of Skunnemunk and Bear Fort Mountains are not included. There appear to be several horizons of conglomerates in the Green Pond Mountain region, viz:

1st. The Macopin Lake, of *lower* Cambrian age;
2d. The Green Pond, Kanouse and Copperas Mountain conglomerate, Ordovician or Silurian;
3d. The white conglomerate west of Greenwood Lake, etc.
4th. The narrow belt of conglomerate beneath the shales carrying the Hamilton fauna, on Greenwood lake, *lower* Devonian.
5th. The massive Devonian conglomerate of Skunnemunk Mountain, which appears to extend to the southwest into Belle-Vale and Bear Fort Mountains.

Of these the 2d and 5th are massive and important formations. The 1st, 3d and 4th are local and appear to be of little stratigraphical importance. With the exception of the 3d, they serve to emphasize the fact shown by the 2d and 5th,—that conglomerates of essentially the same type may be repeated at several horizons within the same basin of sedimentation.

Mr. N. H. Darton informs me that he arrived at essentially the same conclusions from a much more thorough study of the Green Pond Mountain region than I was able to make. He presented his paper at the Boston meeting of the Geological Society of America (Dec., 1893) and I cheerfully yield him priority, as his work was done before I entered the field. These conclusions were not known to me until more than three months after the writing of the preceding notes and after they were in type.

Art. XXXII.—*Notes on Nickeliferous Pyrite from Murray Mine, Sudbury, Ont.;* by T. L. Walker.

The principal nickel ore of the Sudbury district is nickeliferous pyrrhotite. In smaller quantities, nickel occurs in several other forms such as niccolite, gersdorffite, pentlandite, polydymite, and nickeliferous pyrite; these minerals are however often in such quantities as to be of great economic importance. It is intended in the present article to give a few notes on the occurrence of nickeliferous pyrite.

At the Murray mine on the main line of the Canadian Pacific Railway about four miles northwest of Sudbury is found a nickel-iron sulphide containing from four to six per cent of nickel. The writer first had his attention drawn to this mineral in 1891 when assayer at the above mine. Dr. W. L. Goodwin of the Kingston School of Mining published some notes on this mineral in the "Canadian Record of Science" for April, 1893—the specimens then at hand however were massive and somewhat decomposed. The ore occurs in a rock, which on microscopic examination proves to be diorite, which is coarsely crystalline and weathers easily, so that for a few feet below the surface the rock is decomposed and crumbles to pieces when exposed to the air, exposing the kernel-like masses of pyrite. Marcasite (containing no nickel or cobalt), magnetite, galena, chalcopyrite and nickeliferous pyrrhotite are the associated minerals. At first only massive specimens were found, but during the summer of 1893 the mine was again visited and several specimens were obtained showing druses of small bright cubic crystals. These were examined and shown to contain nickel, but as they were very small no quantitative analysis was made of them. The interfacial angles of the crystals were measured under the microscope and found to range from 90° to 90° 40′, which, when it is remembered that the largest crystals measured only ·3^{mm}, is a very close approximation to the cube. The characteristic striæ of pyrite could not be detected. Some of the larger crystals were pressed into a pine splinter and bright surfaces of calcite, fluorite and apatite were in turn scratched. Orthoclase was too hard to be scratched by them—the hardness of the crystals is thus between 5 and 6, which is quite close to that for ordinary pyrite. The mineral strikes fire with the hammer. Specific gravity, color, lustre, and magnetic properties are the same as in ordinary pyrite. The mineral is insoluble in hydrochloric acidbut dissolves readily in nitric acid.

An analysis was made of some of the massive pieces, showing no signs of decomposition, with the following result:

Nickel	4·34%
Iron	39·70
Sulphur	49·31
Moisture	·10
Copper	traces
Insoluble	5·76
Arsenic	none

Seeing that the mineral so closely resembles pyrite, and knowing that iron and nickel are isomorphous in many of their compounds, it is reasonable to regard this mineral as pyrite in which part of the iron is replaced by nickel; its composition will then be represented by the formula $[FeNi]S_2$. When thus considered the above analysis may be represented as follows:

Nickel		4·34%	NiS_2	9·12%
Sulphur	49·31%	4·78		
		44·53	FeS_2	83·49
Iron	39·70	38·96		
		·74	Fe_3O_4	1·02
Oxygen (calculated)		·28		
Water				·10
Insoluble				5·76
Total				99·49%

Doubtless some of the rock-forming minerals, such as chlorite, dissolved in the acids used for solution, but the silica of such would be contained in the insoluble proportion. The small portion of bases belonging to these minerals was not estimated.

A common view with regard to the structure of many of the Sudbury iron-nickel sulphides, is that they are best explained as pyrite or pyrrhotite containing millerite in a finely disseminated form. This would be hard to hold in the present case, for even if we were to consider the whole of the iron as occurring in the form of pyrite (FeS_2), (though we are certain that some of the iron is present as magnetite), the 39·70 per cent of iron would require 45·36 per cent of sulphur, leaving 3·95 per cent sulphur to combine with the 4·34 per cent of nickel. This quantity of nickel in the state of millerite would require only 2·39 per cent sulphur, while in the state of the theoretical di-sulphide (NiS_2) it would require 4·78 per cent sulphur, which is a quantity not very different from that remaining to unite with the nickel, even after *all* the iron has been calculated as pyrite. By allowing ·78 per cent of the iron to be present in the form of magnetite, the agreement between the theory and the analyses is complete.

Professor Penfield in referring to Dr. Emmens' new mineral species blueite, in this Journal for June, 1893, says:

"Although it must be admitted that nickel is a rare constituent of pyrite, yet nickeliferous pyrites are known, and at Sudbury in particular where iron and nickel are so abundant we might expect to find a mutual replacement of these elements."

The notes here submitted show that nickeliferous pyrite *is* found at Sudbury. In a similar way the many other iron-nickel sulphides may be explained as minerals, in which the isomorphous elements iron and nickel replace each other in varying proportions. Doubtless this nickeliferous pyrite is a purer form of the minerals described as whartonite and blueite by Dr. Emmens.

Laboratory of the School of Mining,
Kingston, Ont., February, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Electric Conductivity of Flames.* — Experiments have been made by de Hemptinne to determine the electric conductivity of flames and of gaseous mixtures at the moment of union or of dissociation. The apparatus used consisted of two electrodes of platinum, one connected with a voltaic cell and the other with a capillary electrometer, so arranged that whenever a conducting substance was brought between them, the mercury in the electrometer became of lower potential and moved upward in the capillary tube. When these electrodes were placed in a mixture of nitrogen dioxide and oxygen gases in the act of combining, no effect was perceptible even when the electromotive force employed was 100 volts. The result was equally negative when hydrogen bromide and chlorine, and hydrogen chloride and ammonia, were employed. If the electrodes be placed in the same relative portion of a Bunsen flame however where the combustible gas contains variable quantities of an indifferent gas, the hydrogen flame and the carbon monoxide flame are found to conduct well, the conductivity increasing with the temperature. The experiments on the conductivity of explosive mixtures at the moment of explosion, showed that in the case of oxygen-hydrogen and chlorine-hydrogen mixtures, there is decided conductivity; while in the case of oxygen-carbon monoxide, it exists though in a much less degree. Moreover, although hydrogen chloride and ammonia show no conductivity when uniting, at ordinary temperatures, dissociating ammonium chloride conducts fairly well; as also does ammonium bromide. Vapor of amy-

lene bromide however though dissociated, does not conduct. Nitrogen dioxide is not a conductor.—*Zeitschr. physikal. Chem.*, xii, 244, August, 1893. G. F. B.

2. *On the Electrolysis of Steam.*—The action of electric sparks on steam has been made the subject of investigation by J. J. THOMSON. The steam was passed through the middle limb of a T tube, its closed side limbs being provided with delivery tubes and also with gold or platinum electrodes between which sparks might be passed through the steam. By means of the delivery tubes the gases were conducted into two eudiometers, in which the gaseous mixture which had been formed by the action of the sparks upon the steam, could be exploded. It was noticed that when the sparks were from 1·5 to 4^{mm} long, the volumes of the excess of hydrogen in the one tube and of oxygen in the other, remaining after the explosion of the mixed gases, were, within the limit of error of the experiment, equal respectively to the volumes of the oxygen and hydrogen liberated in a water voltameter placed in series with the steam tube; and further that the excess of hydrogen appeared in the tube which was in connection with the positive electrode, and the excess of oxygen in that which was connected with the negative electrode. If the spark-length be greater than 4^{mm}, the first of the preceding results ceases to hold; and when it reaches 11^{mm} or over, the excess of hydrogen instead of appearing at the positive electrode changes over to the negative; the excess of oxygen at the same time going over to the positive. Reversal again takes place when the length of the sparks is increased to 22^{mm}. The author has further observed that on passing the arc discharge through hydrogen and oxygen respectively, the hydrogen acts as if it had a negative charge and the oxygen as if it had a positive one.—*Proc. Roy. Soc.*, liii, 90; *J. Chem. Soc.*, lxiv, ii, 515, November, 1893. G. F. B.

3. *On the Temperature of Ignition of Gaseous Explosive Mixtures.*—An investigation has been recently made by V. MEYER and MÜNCH to determine the precise point of temperature at which the explosion or silent combination of gaseous mixtures occurs. The mixture to be exploded is contained in a small bulb, placed inside the larger bulb of an air thermometer which was made use of to determine the temperature, this larger bulb being placed in a bath of a fused alloy of lead and tin. The temperature was determined by displacing the air of the thermometer, its volume being known, by hydrogen chloride gas, and measuring this volume over distilled water. As the result of several series of experiments made with four distinct sets of apparatus, the temperature of explosion of electrolytic hydrogen and oxygen was found to vary from 612° to 686°; confirming the theoretical conclusion of Van't Hoff that this mixture does not possess a sharply defined explosion-point. It makes no difference apparently whether the gases are moist or dry; for if dry, silent combination appears to take place to a small extent, thus rendering

them moist before explosion occurs. Sharp solid fragments, such as glass or sea sand were found to be without effect. But fragments of platinum foil or wire made it impossible to bring about an explosion even at 715°, silent union always taking place. Carbon monoxide and oxygen, in suitable proportion to form carbon dioxide united silently in the apparatus, for the most part; the temperatures, when explosion did occur, varying from 636° to 814°. Mixtures of oxygen with gaseous hydrocarbons, excepting perhaps marsh gas, afforded the most trustworthy explosion-temperatures, since there was practically no silent combination. Marsh gas and oxygen explode as a rule, at temperatures varying from 656° to 678°; though sometimes silent and complete combination took place. Ethane and oxygen detonated at 622°, 605° and 622° respectively; ethylene and oxygen at 577°, 590° and 577° in three consecutive experiments. Acetylene with oxygen explodes with remarkable violence, at 510°, 515° and 509°. Propane with five volumes of oxygen, gave 548°, 545° and 548° as the explosion-temperature in three experiments. Propylene, with four and a half volumes of oxygen exploded at 497°, 511° and 499°. Isobutane, with six and a half volumes of oxygen detonated at 549°, 550° and 545°; and isobutylene at 546°, 548° and 537°. Finally coal gas mixed with three volumes of oxygen, was found in three remarkably concordant experiments, to explode at 649°, 647° and 647°. A mixture of coal gas with air could not be exploded however under these conditions of experiment. It will be noticed that the temperature of explosion falls as the content of carbon increases; the mean temperatures, for example, for methane, ethane and propane being 667°, 616° and 547° respectively. Moreover the temperature falls also with the degree of saturation, the less saturated the hydrocarbons, the more readily do they ignite in contact with oxygen; ethane, ethylene and acetylene exploding at 516°, 580° and 511°; propane and propylene at 547° and 504°; and isobutane and isobutylene at 548° and 543°. As might be expected, these differences arising from greater or less saturation diminish as the series is ascended.—*Ber. Berl. Chem. Ges.*, xxvi, 2421, November, 1893.

G. F. B.

4. *On the Composition of Water by Volume.*—By means of improved apparatus, Scott has continued his investigation of the proportion by volume in which hydrogen and oxygen unite. The measurements were all made at constant volume, the pressure only being varied. And as vaselin was found to introduce traces of the oxides of carbon into the gases, syrupy phosphoric acid was used for lubrication. The oxygen was prepared from silver oxide and the hydrogen from sodium and steam. In certain experiments the hydrogen was further purified by absorption in palladium. In five series of 53 experiments the mean ratio of hydrogen to oxygen was found to be $2{\cdot}002435 \pm 0{\cdot}00006$, the impurity being supposed in both gases equally; or $2{\cdot}002431 \pm 0{\cdot}00006$, the impurity supposed in hydrogen alone. Rejecting six

of the experiments the value obtained would be 2·002466 ± 0·000003, the impurity making no difference whether assumed to be all in the hydrogen or equally distributed between the two gases. The most probable value is 2·00245; which combined with Rayleigh's value 15·882 for the ratio of the densities of the gases, gives 15·862 for the atomic mass of oxygen, hydrogen being 1; or 1·0078 for the atomic mass of hydrogen, oxygen being taken as 16.—*Proc. Roy. Soc.*, liii, 130; *J. Chem. Soc.*, lxiv, ii, 575, November, 1893. G. F. B.

5. *On the Production of Hyponitrous acid.*—The results of the reduction of sodium nitrite in alkaline solution have been studied by THUM. He finds that the first product of this reaction is the sodium derivative of a dihydroxylamine, two molecules of which subsequently condense to form sodium hyponitrite:

$$Na_2 + (H_2O)_2 + NaNO_2 = NaN(OH)_2 + (Na(OH))_2$$

and

$$(NaN(OH)_2)_2 = Na_2N_2O_2 + (H_2O)_2$$

This second reaction seems to be favored by an excess of alkali, for if this be neutralized by a current of carbon dioxide, no hyponitrite is formed. The nitrogen which is set free during the reaction is not due to the reduction of hydroxylamine, as usually supposed, for this substance is scarcely attacked by sodium amalgam; it results probably from a reaction between the dihydroxylamine and hydroxylamine $NH_2OH + NH(OH)_2 = N_2 + (H_2O)_2$. For the preparation of hyponitrites, ferrous hydroxide has no advantage over sodium amalgam. Hyponitrous acid may also be formed by the action of nitrous acid on hydroxylamine. When equivalent solutions of hydroxylamine hydrochloride or sulphate and of sodium nitrite are mixed, allowed to stand until the violent evolution of nitrous oxide has ceased and then treated with silver nitrate, silver hyponitrite is formed in amount equal to about 2 per cent of the theoretical yield. In alkaline solution, however, no hyponitrite is formed. The acid itself may be isolated by acting on the silver salt with the theoretical amount of hydrogen chloride. A colorless and strongly acid solution results which is stable towards dilute acids and alkalies even on boiling. On titration with potassium hydroxide, in presence of phenophthalein or litmus, the solution remains acid until the acid salt is formed and then becomes alkaline. The acid does not affect methyl-orange and does not expel carbon dioxide from the alkali-carbonates. In acid solution it is converted by potassium permanganate quantitatively into nitric acid; while in alkaline solution nitrous acid is formed. Pure solutions of hyponitrous acid do not decolorize solutions of iodine and they prevent the formation of iodide of starch. Moreover, they do not liberate iodine from acid solutions of potassium iodide. The acid, in both acid and alkaline solutions, is very stable towards reducing agents. The acid hyponitrites of the alkalies give precipitates with many metallic salts.—*Monatsb.*, xiv, 294; *J. Chem. Soc.*, lxvi, ii, 13, January, 1894. G. F. B.

6. *Potassium and Sodium Carbonyls.*—For some years JOANNIS has been investigating the peculiar compounds potassammonium and sodammonium formed by potassium and sodium respectively with ammonia. He has now studied the reaction which takes place between these substances and carbon monoxide. When dry carbon monoxide is caused to bubble through a solution of potassammonium in liquefied ammonia, the containing vessel being cooled to $-50°$, the deep blue color gradually decreases in intensity and is eventually replaced by a pale pink tint, indicating the end of the reaction. On removing the liquid from the cooling mixture, the ammonia gradually evaporates, leaving a rose-colored powder which analysis shows to be pure potassium carbonyl KCO. It darkens when left undisturbed for some time in a sealed tube. It cannot be heated to the temperature of boiling water, explosion taking place below this point. It likewise detonates if the merest trace of air is admitted, and also when touched with a drop of water. If, however, a drop of water be admitted into an exhausted tube so as not to come in direct contact with the potassium carbonyl, the vapor acts upon it and produces a yellow viscous liquid. If sodammonium be similarly treated, sodium carbonyl NaCO is formed. It is a pale lilac colored substance and is also powerfully explosive, even by small quantities of air or water. When exploded by percussion the reaction was found to be $(NaCO)_4 = Na_2CO_3 + Na_2O + C_3$. Ab90° the explosion is so violent that no glass can withstand it.—*C. R.* cxvi, 1518, 1893.

G. F. B.

II. GEOLOGY AND MINERALOGY.

1. *International Congress of Geologists.*—The sessions of the 6th International Congress of Geologists will be held at Zurich, Switzerland, from the 29th of August to the 2nd of September. As many geologists may not have received the descriptive circulars, the following brief summary of the announcement is made for their benefit.

Besides the general meeting there will be meetings of sections, at the same time, for the following general subjects:

Section 1. General and Structural Geology.
" 2. Stratigraphy and Paleontology.
" 3. Mineralogy and Petrography.

Any person may become a member of the Congress by sending, by postal order, a fee of 25 francs = $5.00 to the Treasurer, M. Casp. Escher-Hess, Bahnhofstrasse, Zürich.

A large number of excursions have been planned for the weeks immediately preceding and following the Zürich meetings. The latter are so arranged as to concentrate at Lugano for the closing session of the Congress on the 16th of September. They are of two kinds. *Pedestrian excursions* for geologists alone, and *Round trips* by rail, steamer and carriage, in which ladies may take part

and which are in charge of the firm of Ruffieux & Ruchonnet, Lausanne.

There are offered to the choice of members of the Congress 5 pedestrian excursions in the Jura for the week preceding the Congress, costing 50 to 60 francs each, and four after the Zürich meeting, of 8 to 13 days each, costing 150 to 250 francs each.

The round trip excursions under the guidance of M.M. Renevier, and Golliez are two in number: 1. In the Jura before the Zürich meeting lasting 13 days and costing 300 francs: 2. After the Zürich meeting, in the Alps, lasting 13 days and costing 400 francs. Some supplementary excursions are also planned. A geological guide book, giving details of all the excursions is in preparation, and will be issued before the meeting of the Congress to those who remit to the Treasurer its cost, viz: 10 francs.

Geologists who wish to attend the Congress can send their names and addresses to S. F. Emmons, Sec'y, 1330 F St., Washington, who will undertake to forward them to Switzerland so that descriptive circulars and accompanying blanks may be sent them, or they can send their fee (including the cost of guide-book if they desire it) to the Treasurer, who will thereupon forward the circulars to them, and they may thus be able to designate what excursions, if any, they desire to take part in.

2. *Geological Survey of the State of New York, Palæontology:* Volume VIII. *An Introduction to the study of the genera of Palæozoic Brachiopoda;* by JAMES HALL, assisted by JOHN M. CLARKE. Part II. Fascicle I, July, 1893. Fascicle II, December, 1893.—The delay in the publication of this volume has made it desirable for the authors to issue a limited edition in fascicles, which together with the plates will make the completed volume. The first treats of the genera of palæozoic spire-bearing brachiopods, and the second of the rhynchonelloids, pentameroids, and loop-bearing forms. The limitations of old genera are now clearly defined and many new generic terms are proposed. A review of the entire volume, when complete, will be given.

C. E. B.

3. *Alabama Geological Survey: Report on the Coal Measures of Blount Mountain,* with map, and sections, by A. M. GIBSON, Assistant Geologist. 80 pp. Montgomery, 1893.

This is a coal field in North-central Alabama, not now worked, of about one hundred and fifty square miles, lying between the already described and worked Warrior (northwest) and Cahaba (southeast) Coal fields of Alabama, of which the author gives a detailed description.

4. *Geological Survey of Texas, 4th Annual Report for 1892.* E. T. DUMBLE, *State Geologist.*—The parts 10 and 11 and the Report of the state geologist have appeared, thus completing the fourth volume (see this Journal, vol. xlvi, p. 307, and xlvii, p. 160). Part 10 contains a preliminary list of the land, fresh water and Marine *Mollusca of Texas,* pp. 299–343; and a chapter on *Texas birds,* pp. 345–375 by J. A. SINGLEY. Part 11, is a second

paper on *Carboniferous Cephalopods*, by ALPHEUS HYATT, pp. 377–474, in which a number of new genera and species are figured and described.

5. *Outline of the Geology and Physical Features of Maryland*, with a new geological map of the State and 16 plates; by G. H. WILLIAMS and W. B. CLARK. 4°, 67 pp. Johns Hopkins University Press, Baltimore, 1893; price $1.00—This book is a reprint of the chapters relating to Physical Geography and Geology from the large work on Maryland and its resources, prepared by members of the Johns Hopkins University faculty for the Columbian Exposition. Its first part deals with topography and climate, and is illustrated by many tables and five colored charts which show the distribution of temperature and precipitation in each season and throughout the year. The second part is descriptive of the geology in each of the three great provinces of Maryland—Coastal Plain, Piedmont Plateau and Mountains—and is followed by an historical review of the sequence of events by which the remarkably complete series of geological formations occurring within the State has been deposited and brought into its present position. This part is embellished by ten full-page plates which exhibit the various types of topography, and by a new geological map in colors on a scale of eight miles to the inch. This map also gives the distribution of soils by Prof. Milton Whitney. G. H. W.

6. *Lehrbuch der Petrographie* von Dr. FERDINAND ZIRKEL, Ord. Professor der Mineralogie und Geognosie an der Universität, Leipzig. Zweite, gänzlich neu verfasste auflage. Zweiter Band. 941 pp. 8vo. Leipsic, 1894. (Verlag von Wilhelm Engelmann.)—The first volume of Prof. Zirkel's excellent Lehrbuch was noticed in the last volume of this Journal. This second volume, which extends to 941 pages, treats, under the head of Special Petrography, of part of the massive crystalline rocks, and includes those containing alkali-feldspar and quartz; alkali-feldspar without quartz, nephelite or leucite; alkali-feldspar without quartz, but with nephelite or leucite; and those of lime-soda feldspar without nephelite or leucite. The subject will be continued in the third volume.

7. *Geological Survey of Portugal: Description de la Faune Jurassique du Portugal. Classe des Céphalopodes*, by PAUL CHOFFAT. 1st series: Ammonites du Lusitanien de la contrée de Torres-Vedras. pp. 82, 20 quarto plates, Lisbonne, 1893.—This memoir contains descriptions of species of Cardioceras, Phylloceras, Lytoceras, Harpoceras, Ochetoceras, Oppelia, Neumayria, Olcostephanus, Perisphinctes, Aspidoceras, Peltoceras, Simoceras, Hoplites.

8. *Untersuchungen über Fossile Hölzer Schwedens;* by H. CONWENTZ. pp. 99, 11 quarto plates. K. Schwedischen Acad. Wissenschaften, Ser. C, No. 120, Stockholm, 1892, contains descriptions of fossil plants from the Halma sandstones, from the drift of Sweden, and comparisons of the latter with the former, the authors

reaching the conclusion that North German, Danish and Swedish fossil drift-wood has not been derived from the Halma-Sandstone (Cretaceous) in S. Sweden but that the great majority of it has had its origin in Tertiary deposits at no great distance;

9. *Swedish lower Paleozoic Hyolithes and Conulariæ. Sveriges Kambrisk-Siluriska Hyolithidæ och Conulariedæ*, af GERHARD HOLM, from the afbandlingar of the Sveriges geologiska undersökuing, Ser. C., No 112, pp. 1–172 and 6 quarto plates. Stockholm, 1892.—Gerhard Holm has given, in this monograph on the interesting and little known extinct organisms of Sweden an exhaustive list of the known species classified and tabulated according to their range, distribution and supposed genetic affinities. 41 new species of the Hyolithiidæ, 10 new Conulariidæ and one new species of the Torellellidæ are described. An English summary of characters and classification is given at the close of the volume.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *British Association for the Advancement of Science.*—The sixty-fourth meeting of the British Association will be held in Oxford, under the Presidency of the Marquis of Salisbury, Chancellor of the University, in the week beginning August 8th, 1894.

2. *A History of Mathematics;* by FLORIAN CAJORI.—Macmillan and Co., New York, 1894. 8°, pp. xiv, 422.—The first third of Professor Cajori's book is devoted to the history of methematics among the Babylonians, Egyptians, Greeks (including the Alexandrian schools), Romans, Hindoos, Arabs, and Europe during the Middle Ages. The second third traces the development of the science from the beginning of the sixteenth to the early part of the nineteenth century. The recent developments of the science are then treated in several lines, Synthetic Geometry, Analytic Geometry, Algebra, Analysis, Theory of Functions, Theory of Numbers, and Applied Mathematics. The volume has an exceedingly convenient index filling seventeen pages.

No science can be thoroughly comprehended until its history has been learned. Professor Cajori has given the history of Mathematics in an interesting form, and teachers and students of the science have reason to thank him for it. H. A. N.

3. *The Ejected Blocks of Monte Somma,—Part I, Stratified Limestones;* by H. J. JOHNSTON-LAVIS.—The following extract from the article of above title in the Transactions of the Edinburgh Geological Society (vol. vi, 1893, pp. 347–350), contains the interesting conclusions reached by the author from study of a large number of specimens:

"Such are the specimens of stratified limestones which are to serve as clues to the remarkable series of reactions that have converted cretaceous limestones into a series of rocks that, by themselves, one would hardly dare to suppose once to have been nothing more than an impure dolomitic limestone. I do not

doubt that it will be argued that changes that occur in such small specimens should not be used as a guide to what occurs in large masses. To this it may be answered that the greater number of chemical phenomena that occur in the mineral world can be studied on the smallest scale in the laboratory. But beyond this these very same metamorphic changes may be traced on a much grander scale amongst the ejected blocks of Monte Somma, and I propose to confirm and extend these few notes in another paper on the massive limestones and their derivatives.

"Further, when we extend our investigations to the contact phenomena of such a region as the Tyrol, which are probably of less importance than what is really going on beneath Vesuvius, and from thence pass to areas of regional metamorphism, we are struck by the great similarity in the changes that have taken place. It must, however, be borne in mind that three important factors enter into the question, namely, the composition of the rock to be acted upon, that of the magma acting, and the time, circulation, and quantity of the latter. And equally imperative is it to remember that such rocks which reach the surface by denudation of the overlying materials have been exposed to so many fresh changes as sometimes to be no longer recognizable.

"The changes that take place in an impure limestone seem to be, in the first place, the carbonization of the bituminous contents with the conversion of them into graphite. Almost coincidentally re-crystallization seems to have taken place, for what was an extremely fine-grained rock begins to approach the saccharoidal structure. This re-arrangement or re-crystallization seems to have occurred without the rock having become fused, or even pasty, since the most delicate stratification, banding, faulting, and contortion structure is preserved. At this stage a few grains of peridote begin to make their appearance, chiefly as inclusions within the calcite crystals. The next process is the destruction of the graphite, and in some cases its apparent replacement by peridote, as in specimen No. 200. In the early stages of carbonization the graphite exists between the grains, but later gets enclosed within them, as if they had undergone fusion. With the disappearance of the graphite, what remains is a more or less coarse-grained, dazzling white marble. This saccharoidal marble, containing more or less white peridote, passes somewhat abruptly into a mass of peridote and white pyroxene, wollastonite, or biotite. Why, sometimes it is one or sometimes another mineral that borders on the white marble, I feel inclined to attribute to the impurities in the original limestone in the absence of alumina, with a supply, though limited, of silica, with much lime and magnesia, so that either fosterite or monticellite may result, and, if much iron, even true olivine may separate out. If only silica and lime are present, then we must look for wollastonite. Likewise, the presence of fluorine may determine the crystallization of humite instead of peridote. In the same way we understand how the other minerals may separate. Now, in a stratified lime-

stone, some bands will be more argillaceous, siliceous, ferriferous, or magnesian, or two or more of these impurities may abound, so that in a stratified rock of this kind, the minerals developed in one band will differ from those in another, as is so strikingly shown in specimen No. 41.

"This metamorphism is selective only in the early stages, for (as in 36, 54, and 40) we have the silicate bands encroaching upon the intervening marble strata; whilst in 44, the well stratified portion, toward the metamorphosing focus, is fused (?) up into a fairly homogeneous mass of coarser grains and larger crystals of the same minerals as in the undisturbed part, together with the addition of others. Yet that the composition of the bands has a strong determining influence on the results is well illustrated in No. 51.

"The order in which the new minerals seem to develop is the following:

(1) Peridote, Periclase, Humite.
(2) Spinel, Mica, Fluorite, Galena, Pyrites, Wollastonite.
(3) Garnet, Idocrase, Nepheline, Sodalite, Feldspar.
(4) Calcite (secondary).

"Although in some cases there is an approach to the order of mineral species found in the druse walls described by Mierisch (*loc. cit.* p. 121), yet these are exceptional, and open up for our investigation a far wider field of facts.

"It is evident that any researches as to the purely chemical changes that take place in the process of metamorphism would be useless in stratified limestones unless it were possible to know the composition of each band. It will therefore be better to consider these questions where treating of the massive limestones and their derivatives.

"Then also, it is necessary to study the changes that have taken place in the minerals originally replacing the limestone. We have distinct evidence of the conversion of periclase into brucite, and of peridote to a whitish fibrous mineral or pilite (?) The biotite, nephelene, feldspar (?) and peridote may be crowded with microliths, which there is good reason to believe consist of pyroxene.

"Another point of interest is that I have not so far noticed the presence of periclase in any rock where graphite could be detected. This might well be explained by the fact that so long as free carbon remained, the magnesia would be maintained as carbonate, and only on its loss of the CO_2 could it take up the SiO_2 to form fosterite, or, with the addition of lime, monticellite; or should silica be absent, to combine with any alumina and to separate as spinel.

"Specimen 51 indicates, at any rate, that the latter result is subsequent to the former. Certainly 200 is curious, as showing an apparent displacement of the carbon grains by peridote, although it may be that that mineral simply occupies the spaces left by the disappearing carbon.

"It is also necessary at the same time to remember the chemical relationship of carbon and silicon. Another point is, that in all probability the first minerals produced by metamorphism are elaborated from materials contained within the rocks themselves; but eventually other constituents are added, or are removed, by the circulation of water, by vapors, or by diffusion from neighboring rock masses or igneous magma. Cossa found that he could reproduce periclase by heating for some hours magnesic sulphate and sodic chloride, and obtained still larger crystals by adding a little ferrous sulphate. This, however, is hardly likely to be the process of formation in the rocks beneath Vesuvius. Deville reproduced periclase by acting on magnesia by hydrochloric acid gas, and Daubrée by the action of magnesic chloride on lime. There is good reason to believe that it was by one or both of the latter processes that resulted in the production of periclase in the magnesian limestone, especially when we take into consideration the great abundance of hydrochloric acid and chlorides contained within the neighboring incandescent lava of Vesuvius. The artificial reproduction of fosterite by Ebelmen probably is a near imitation of what occurred in its natural production.

"In fine, we see a definite order of chemical changes occurring in Jurassic and Cretaceous limestone, which may convert that rock into a granitic mass of crystallized basic silicates and oxides, etc., which may in their turn by decomposition, give rise to a group of rocks in which the original constituents would be represented by serpentine and its varieties, Tremolite, Brucite, etc., an association which prevails amongst metamorphic rocks that are exposed at the surface by that series of precarious events constituting denudation.

"With regard to the removal of the lime in these metamorphosed rocks, Mierisch (*loc. cit.* p. 187) supposes the excess to have been carried off as chloride by fumarolic action, and thinks that the small quantity deposited around fumaroles proof of such being the case. Without laying stress on the latter, we may admit that this is very probable; may it not, however, be that much of the lime is retained in the lava, being utilized in the formation of some or all the lime-bearing crystal components, whilst the HCl would volatilize, as we know it does do, very largely from the volcanic vent.

"As Mierisch has to a great extent exhausted the description of the drusy limestones, it is proposed in the next paper to treat of the massive limestones, their alteration, metamorphism, and their derivatives."

The average elevation of the United States, by HENRY GANNETT, (extract from the 13th Ann. Rept. of the Director of the U. S. Geol. Survey, 1891-92. pp. 282-289 and colored Relief Maps of the United States.

The Mechanics of Appalachian Structure, by BAILEY WILLIS. (Extract from the 13th Annual Report of the Directors. U. S. Geological Survey 1891-92, pp. 211-281 and Plates XLVI-XCVI.) Washington, 1894.

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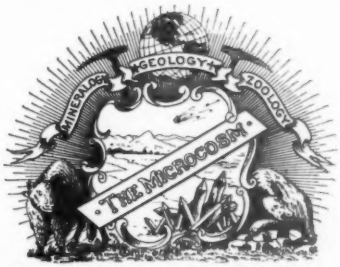

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